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TOWARDS AUTOMATION OF IRRIGATION SYSTEM

With Special Reference to Gezira Scheme

By

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بسم ا   الرحمن الرحيم

قال تعالي: " أولم يرو أنا نسوق الماء إلى الأرض الجرز فنخرج به زرعا تأكل منه أنعامهم وأنفسهم أفلا يبصرون ". السجدة – الآية (27).

قال تعالي: " ألم تر أن ا   أنزل من السماء ماء فأخرجنا به ثمرات مختلفا ألوانها " سورة (فاطر) الآية (27)

صدق ا   العظيم

Dedication

This thesis is dedicated to my beloved

Mother,

Father,

Wife,

Son,

Brothers, and

To all those who helped me in this research in one way or another.

Acknowledgment

I am greatly indebted to my supervisor Dr. Adil Mohamed El-Khidir for initiating this research and teaching me the basics of scientific research. I wish to express my gratitude to him. His patience, keen supervision and expert advice are gratefully acknowledged.

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Abstract

Automation is used to simplify and reduce or replace the decision-making process of the operators, and to implement a decision. It has increasingly been used to improve the effectiveness and to reduce the cost of water supply operations.

The purposes of thesis is to set a daily basis operation program for 'Rewina' canal system, the `program includes the irrigation schedules for crops, irrigation depth, daily areas to be irrigated and quantities of water flows passing through irrigation structures.

Thesis applied (theoretically) automation on the irrigation system, which includes input data (monitored by sensors), that transmitted by telecommunication system to the central control room, which will be analyzed to determine the total areas to be irrigated on daily basis, discharges required and the number of structures to be operated to pass the required discharges. The input data includes field moisture contents, upstream and downstream water levels besides the initial position(s) of gate(s) for each irrigation structure. The output data includes the final position(s) of gate(s) for each irrigation structure, which will be transmitted by telecommunication system from the central control room to the field level for execution, by the motor erected in each gate.

ملخص

تستخدم عملية التحكم الأوتوماتيكي بصورة عامة لتبسيط وتقليل عملية اتخاذ القرار الخاص بتشغيل الأبواب. وقد تم استخدام التحكم الأوتوماتيكي بشكل واسع لزيادة فعالية عملية إمداد وتشغيل مياه الري وتقليل التكلفة.

إن الأغراض الرئيسية من هذه الدراسة تكمن في وضع برنامج تشغيل يعمل علي أساس يومي لقناة "**روينا**" **قسم ري "كاب الجـداد**" حيث يشمل البرنامج علي جدول يوضح الخصائص المتعلقة بعمق مياه الري المطلوبة، والمساحات المروية يومياً، وكمية التصرفات المارة خلال منشآت الري بالمشروع، كما تم اتخاذ البرنامج اليومي المتبع كأساس للتشغيل الأوتوماتيكي.

طبقت الدراسة (نظرياً) عملية تشغيل نظام ري أوتوماتيكي، والذي يتضمن عملية إدخال البيانات (بواسطة المجسات)، والتي ترسل بواسطة نظام اتصالات إلي غرفة التحكم المركزي لتحليلها ولحساب المساحات الكلية المروية يومياً، والتصرفات المطلوبة، وعدد المنشآت (الأبواب) المطلوب تشغيلها لتمرير التصرفات. حيث تتضمن البيانات المرسلة بواسطة المجسات درجة رطوبة التربة ومناسيب الأمام والخلف هذا بالإضافة إلي مقدار الفتحة الأولية للبوابة (البوابات) لكل منشأة ري. وتتلخص النتائج النهائية في إيجاد مقدار الفتحة النهائية للبوابة (البوابات) لكل منشأة ري. وترسل هذه النتائج النهائية بواسطة نظام اتصالات من غرفة التحكم المركزي إلي المشروع للتنفيذ.

Abbreviations

ADCP	Automatic Doppler Current Profiler
BL	Bed Level
CCWR	Cumulative Crop Water Requirement
CMS	Central Monitoring System
d	Water Depth
DAS	Data Acquisition System
D/S	Downstream Water Level
DWLC	Downstream Water Level Control
EIT	Environmental Information Technology
ET	Evapotranspiration
FB	Free Board
FCC	Federal Communication Commission
Fd	Feddan (0.42 ha)
FDC	Farmer’s Development Centers
FSL	Full Supply Level
GN	Ground Nut
GOC	Gate Opening Control
GP	Gate Position
GPC	Gate Position Control
I/O	Input-Output
LDC	Less-Development Countries
LIPDs	Licence for low Interference Potential Devices
LPS	liter per second
MOIWR	Ministry of Irrigation and Water Resources

OPC	Office Personal Computer
PC	Personal Computer
PLC	Programmable Logic Control
PID	Proportional Integral Derivative
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCP	Societe du Canal de Provence (شركة فرنسية)
TBL	Top Bed Level
U/S	Upstream Water Level
UWLC	Upstream Water Level Control
VHF	Very High Frequency
WAN	Wide Area Network
WFC	Water Flow Control
WS	Water Surface

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Chapter One

Introduction

Chapter One

Introduction

1.1 The Nile Water:

River Nile is one of the largest rivers in the world and life is directly dependant upon it in the Sudan. It represents a link between different cultures, ecological systems and different climates. The length of the Nile is 6,700 km with a basin of 3.0 million km^2 equal to 10% of Africa total area. Nile River water passes through ten African countries Sudan – Egypt – Ethiopia – Eritrea – Democratic Republic of Congo – Uganda – Kenya – Rwanda – Burundi – Tanzania. The annual average of White Nile supply at Khartoum is estimated at 27 Milliard cubic meters (Mcm) and the natural supply of the Blue Nile at the same point in addition to its two tributaries Dinder and Rahad is 54 Mcm. As for Atbara River, the natural annual supply is 12 Mcm. Thus, the total annual supply of the River Nile along with its tributaries at the middle of Sudan is 93 Mcm; however, the average annual supply of the River Nile at Aswan is estimated at 84 Mcm.

1.2 Sudan Water Consumption:

The current rates of consumption for Nile tributaries (White Nile, Blue Nile, and Atbara River) and the Main Nile are shown in Table (1.1). The evaporation losses that take place at dams such as Roseries, Sennar, and Girba are shown in Table (1.2). In addition, other uses for Nile water such as drinking water for human, animals and the industrial sector are shown Table (1.3). The total Sudan consumption is 15.530 Milliard m^3 at mid Sudan equivalent to 14 Milliard m^3 at Aswan dam.

Table (1.1): Sudan water consumption from the Nile system (Year 2002)

River	Potential Arable Area (Million Fd)	Irrigated Area (Million Fd)	Water Demand (Milliards m^3)
Blue Nile	6.2715	2.112	9.050
White Nile	1.791	0.480	2.050
Atbara River	1.361	0.282	1.270
Main Nile	N.A*	0.311	1.200

N.A*: Not Available

Reference MOIWR Records

Table (1.2): Evaporation losses in Reservoirs (Year 2002)

River	Scheme	Evaporation Losses (Million m^3)
Blue Nile	Rosaries Dam Sennar Dam	410 300
Atbara River	Khashm Elgirba Dam	170

Reference MOIWR Records

Table (1.3): Different Usages (Year 2002)

Type of Usage	Demand (Million m^3)
Human (Urban and Rural)	280
Animal	740
Others	60
Total	1080

Reference MOIWR Records

Sudan is a large country in terms of area and climatic diversity. The northern part is divided between Sahara and Semi-Sahara except the areas that extending with the Nile. Rainfall rates ranges from zero in the north to 1000 mm in the far south. River Nile is the most important water resources in Sudan.

With regard to the schemes that aim at raising water supply by reducing water losses in the swamps in the south, the annual loss rate is estimated to be 36 Milliard cubic meters. There are joint future projects between Sudan and Egypt to save some of this amount. Potential benefit from these projects is estimated at four Milliard cubic meters at the first stage for Jungile canal and 7 Milliard cubic meters from Bahr Al-Gazal basin project and 7 Milliard cubic meters from Subatt project, the completion of these project will contribute to the agricultural expansion in the future.

Sudan exploited only 15.530 Milliard cubic meters from his quota, which is 20.5 Milliard cubic meters. Also, there is a future plan to utilize the 5 Milliard cubic meters of the Nile water through the heightening of Roseries dam, setting up Kenana and Rahad canals (second phase), the pumps projects on the Blue Nile and rehabilitation of current irrigation projects.

1.3 Gezira Scheme:

The Gezira irrigation Scheme lies between the Blue and White Nile rivers south of Khartoum, and is fed principally by gravity irrigation from Sennar dam on the Blue Nile. It has grown from the original scheme cultivating 300,000 fd to present irrigation area of 2.1 million fd (about 882,000 ha, one feddan (fd) = 0.42 ha). The climatic conditions are favorable to year-round cultivation, and the physical properties of the impermeable clay soils show a tendency to water logging, which badly depress the yields. Despite sixty-five years of irrigation, salinity is not a problem with the exception of some fringe areas on drier zones near Khartoum. Blue Nile water is silt-laden during the flood season (MOIWR magazine 2000).

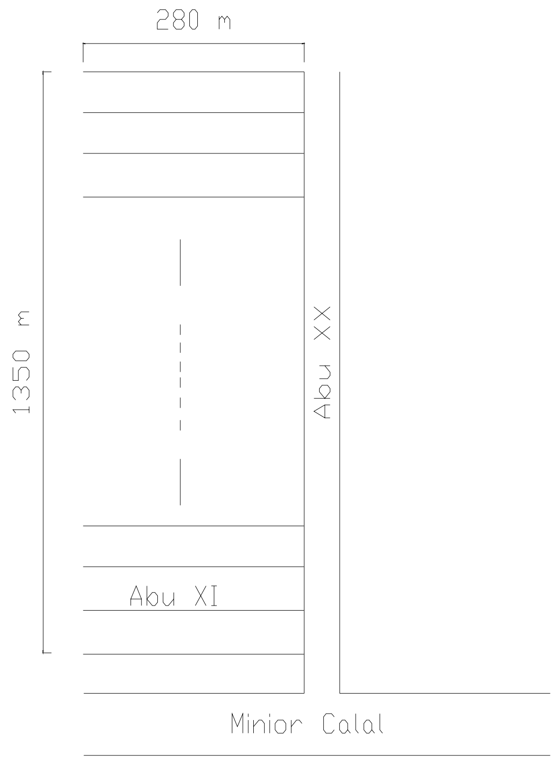
The Sennar diversion dam built in 1925 regulates the flow of the Blue Nile. The Gezira scheme was designed in the 1920's after prolonged experiments had been carried out on a prototype scale. It was designed with the main objective of producing cotton, a single cash crop. It was thus a non-perennial scheme with monoculture. Other crops were initially grown to provide food for the tenant farmers, and to help in the maintenance of soil fertility. Cotton, wheat, groundnut and sorghum are now cultivated in a fifth-course rotation, including fallow (MOIWR magazine 2000).

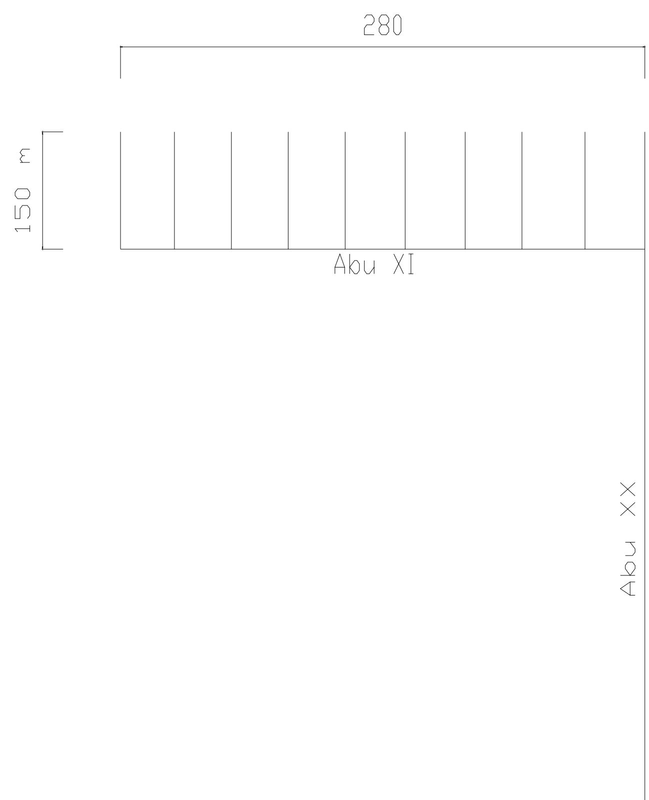
The main, branch and major canals are designed as regime conveyance channels. The minor canals are designed for storing water continuously flowing from the major canals at night. The rough rules of thumb developed for the operation of the scheme of such a large scale were the result of insufficient knowledge about the crop requirements under Gezira soil and climatic conditions. According to the design principle, the nominal flow in AbuXX is 5,000 m^3/ day.

Crop intensification, expansion of the system, breakdown of the communication system, and insufficiently funded maintenance critically resulted in improper use of the system and inadequate control (MOIWR magazine, 2001). Due to the deterioration of the movable weirs and their sensitivity to the fluctuating water levels in the major canals, it become difficult to maintain the indented discharge into the minor canals (MOIWR magazine, 2001).

The imposition of discipline and the re-institution of the old regulations may be counter-productive especially during the summer rains, which disturb any pre-arranged schedule. In this period, management consisted of day-to-day decision, with proper field drainage deserving high priority (Saeed Mohamed Farah, 2000).

The field efficiency in the Gezira is estimated at about 75%, assuming usual definition of crop water requirements, which exclude the field losses, and the overall efficiency is 70% (MOIWR magazine, 2000). This value is the highest found in surface irrigation project due to the nature of the soil (MOIWR magazine, 2000). The high clay content of the soils in the Gezira plain and the design of the distribution systems are the two main reasons for this high efficiency (MOIWR magazine, 2000). If the major and minor canals are clean from silt and weed, there would be an equitable water distribution.


280 m
1350 m
Abu XX
Abu XI
Minior Calal


280
150 m
Abu XI
Abu XX

1.4 Irrigation in Gezira Scheme:

Irrigation water for the Gezira scheme is diverted from the Blue Nile at Sennar dam. The Blue Nile water hydrology, suitability, and the quality for irrigation are excellent and overall availability of water to the project from Sudan's share of the Nile waters is adequate for the needs.

The distribution system serving 1.10 million feddans in Gezira and about 1.0 million in Managil, comprises 260 km of main canals, 588 km of branch canals, 1601 km of major canals, and 7835 km of minor canals.

The irrigation system adopted in Gezira scheme consists of straight minor canals with length 1420 m from main canals. These sub-canals are barreled and the distance between each one is constant (280 m). Each minor-canal gets its water through a gate equipped by pipe leading to the sub-canal. The minor-canal also divided to Abu-XXs that run in a straight line with length of 1400 m and it stops before reaching the next minor-canal.

The rectangulars of 90 feddans that are located between two sub-canals and two Abu-XX are known as the 'Blocks', each one of these blocks is divided to smaller parts and irrigated by small tributaries branching from Abu-XXs and known as Abu-VIs.

At the beginning of operation of the scheme, the canals were basically designed to irrigate limited areas planted by cotton, where the gate-keeper was responsible for controlling the irrigation process, release the water from Abu-XX for seven days on schedule base. During this period, the farmers of the upper part of the block will be enabled to take enough water to irrigate. Then the chance is given to the farmers of the lower part of the same block and thus cotton could be irrigated every two weeks with water depth reaching 10 cm.

1.5 Automation:

Canal automation refers to closed – loop control in which a gate change its position /setting in response to water level, flow rate or pressure because that level /rate/ pressure is different from the intended target value. Closed loop' means that the action is performed without any human intervention .The automation may be performed through hydraulic, electrical, electronic or a combination of these, means. As it eliminates uncertainties and inadequacies of human interventions, automation of some degree is acknowledged as an efficient means to simplify operation, increase the reliability and flexibility of deliveries and reduce operational water losses.

1.6 Scope of Work:

1. To set a daily basis operation program for 'Rewina' canal system in Kab-Elgiddad sub-division of Gezira scheme. The program includes the irrigation schedules for crops, irrigation depth, daily areas to be irrigated and quantities of water flows passing through irrigation structures.
2. This operation program has been used as a base towards the automation of 'Rewina' canal system.
3. Automation of canal system requires input data to be transmitted by telecommunication system to the central control room. Input data include field moisture contents, upstream and downstream water levels besides the initial position of gate(s) for each irrigation structure. The output data such as the final position of gate(s) for each structure will be sent from the central control room, by telecommunication system, to the considered irrigation structure for execution.

Chapter - Two

Study Case

Rewina Canal System
Gazira Scheme

Chapter Two

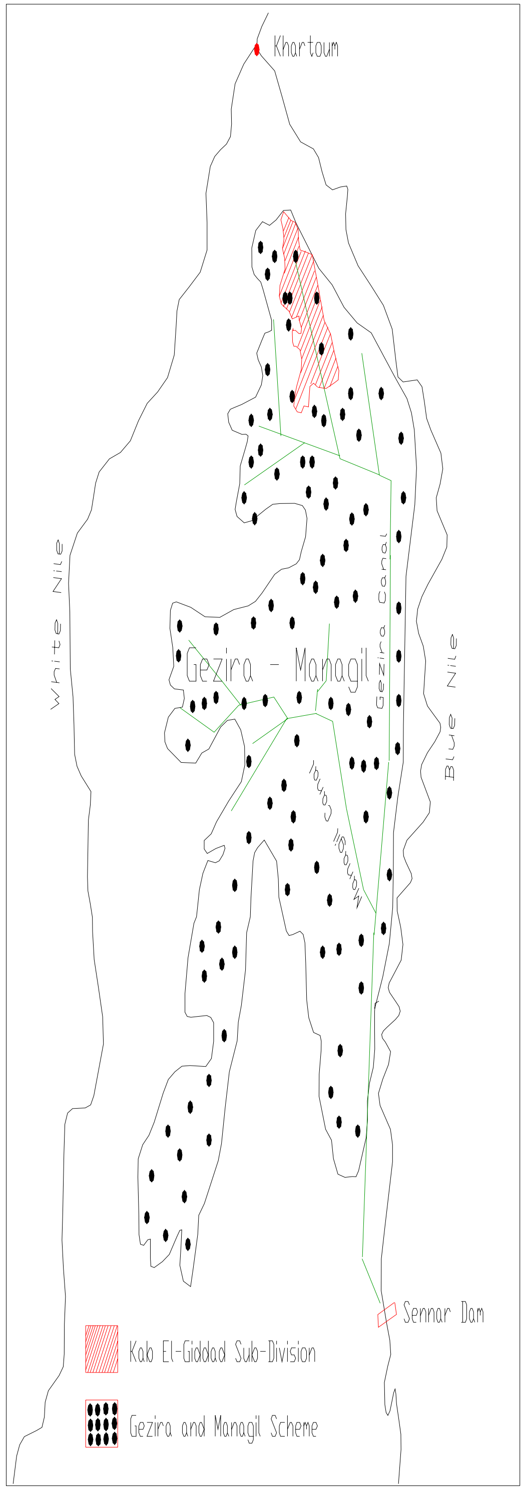
Study Case
Rewina Canal System
(Gezira Scheme)

2.1 Location:

Sudan extends between latitude 4^0 and 22^0 North and longitude 22^0 and 38^0 East with an area of 2.5 millions km^2 approximately. Zones north of 14^0 latitude regarded as dry areas and totally dependent on the River Nile for Agriculture. Sudan also is one of the tropical countries that characterized by its hot climate and there is no vast difference between its season in term of temperature. The average annual temperature is about 30^0, and the average annual rainfall is 400 mm.

Kab El-Giddad sub-division is located in the north of Gezira scheme between longitude $32^0\ 42^/$ - $33^0\ 05^/$ East, and latitude $14^0\ 45^/$ - $15^0\ 15^/$ North (Fig.2.1). The total irrigated area of Kab El-Giddad sub-division is 161,000 feddan, where area irrigated by Rewina major canal is 6,100 feddan. Rewina major canal branched from the western-north branch at 22 kilometer, which comes from main canal of Gezira scheme at 156 kilometer.

Fig. (2.1) Kab El-Giddad sub-division Location



Source: MIWR, 1978, Nile Water Study, Sudan

2.2 Water Supplies:

The Blue Nile is the source of the water supply for the Gezira Scheme. The river is known for its marked seasonal and annual variations. It has an average annual flow of 50-milliard m^3 and contributes about 68% to the yield of the Nile. The seasonal variation of its discharge ranges from over 10,000 m^3/s at the peak of a high flood to 60 m^3/s in a very low year. Analysis of water quality shows that the Blue Nile water is suitable for irrigation.

2.3 Cropping Patterns:

The total area irrigated under study is 6100 feddan, where the area of holding for each farmer is 20 feddan, and the area of 'hawasha' is 4 feddan.

From Table (2.1), the design factor (F) has been found as follows:

$$F= 3.46*10^6/ (6100 * 31 * \text{irrigation efficiency}) \qquad (2\text{-}1)$$

Where,

The factor 3.46 is the maximum irrigated water requirement, which occur in month **October**, (Million m^3/month)

10^6: conversion factor from Million m^3 to m^3

6100: irrigated study area (feddans)

31: number of days of month **October**

Overall irrigation efficiency is 0.85,

Resulted design factor (F) is 21.5 m^3/fed./day

Table (2.1): Seasonal crop water requirements data and Monthly Irrigation Requirements.

	ET_{crop} m^3/fed								
Crop	Jan	Feb	Jun	July	Aug	Sep	Oct	Nov	Dec
G.N (1220F)			407	700	868	924	681	156	
Dura (1220F)				598	910	936	434		
Wheat (1220F)	564	134					147	652	806
Cotton (1220F)	634	377		169	464	714	976	892	774
Total IWR (Million m^3/month)	1.46	0.62	0.50	1.79	2.74	3.14	3.46	2.07	1.93

Source: (Farbrother, 1976)

Table (2.2): Irrigation seasons for grown crops for 'Rewina' canal system.

	T I M E S P A N											
Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ground Nuts (G.N)												
Dura												
Wheat												
Fallow												
Cotton												

Table (2.3): Gezira scheme cropping patterns

G.N	Dura	Wheat	Fallow	Cotton
20 %	20 %	20 %	20 %	20 %

Table (2.4): Cropping intensities for Rewina canal system

G.N	Dura	Wheat	Fallow	Cotton
1220 Feddan	1220 Feddan	1220 Feddan	1220 Feddan	1220 Feddan

Table (2.5a): Description of 'Rewina' canal system

Minor Canal	**No. of Abu xx**	**Type of off-take Structure**	**Area Irrigated (Fd)**	**Discharge (m^3/sec)**	**Discharge (m^3/day)**
Minor-1	11	W.H.R/1* 0.91	706	0.18	15,179
Minor-2	6	W.H.R/1* 0.76	353	0.09	7,590
Minor-3	11	W.H.R/1* 0.76	724	0.18	15,566
Minor-4	8	W.H.R/1* 0.76	333	0.08	7,160
Minor-5	11	W.H.R/1* 0.91	694	0.17	14,921
Minor-6	9	W.H.R/1* 0.76	255	0.06	5,482
Minor-7	11	W.H.R/1* 0.76	666	0.17	14,319
Minor-8	9	W.H.R/1* 0.76	600	0.15	12,900
Minor-9	11	W.H.R/1* 0.76	724	0.18	15,566
Minor-10	9	W.H.R/1* 0.76	488	0.12	10,492
Minor-11	11	W.H.R/1* 0.76	474	0.12	10,191
Minor-12	4	P.R/1* 0.50	83	0.02	1,784

Table (2.5b)

Major	**No. of Minors Canal**	**Type of off-take Structure**	**Area Irrigated (Fd)**	**Discharge m^3/sec**	**Discharge (m^3/day)**
Rewina	12	P.R/3*0.91	6100	1.52	131,150

Table (2.6) Irrigation Scheduling for **Cotton**:

Irrigation Interval (Days)	**Irrigated Area (Fd)**	**Discharge (m^3/day)**
27	45.2	18,080
24	50.8	20,320
16	76.2	30,480
13	93.8	37,520
13	93.8	37,520
12	101.7	40,680
13	93.8	37,520
15	81.3	32,520
15	81.3	32,520
15	81.3	32,520
21	58.1	23,240
21	58.1	23,240

Table (2.7) Irrigation Scheduling for **Groundnut**:

Irrigation Interval (Days)	**Irrigated Area (Fd)**	**Discharge (m^3/day)**
20	61	24,400
18	67.8	27,120
16	76.2	30,480
15	81.3	32,520
13	93.8	37,520
13	93.8	37,520
14	87.1	34,840
15	81.3	32,520
20	61	24,400

Table (2.8) Irrigation Scheduling for **Wheat**:

Irrigation Interval (Days)	**Irrigated Area (Fd)**	**Discharge (m^3/day)**
24	50.8	32,320
17	71.8	28,720
15	81.3	32,520
15	81.3	32,520
21	58.1	23,240

Table (2.9) Irrigation Scheduling for **Dura**:

Irrigation Interval (Days)	**Irrigated Area (Fd)**	**Discharge (m^3/day)**
22	55.5	22,200
16	76.2	30,480
14	87.1	34,840
12	101.7	40,680
14	87.1	34,840
12	101.7	40,680
18	67.8	27,120

Table (2.13): Daily **GROUND NUT** Irrigated Areas (in Feddan) for Different Minors,
Irrigation period (1st Jun - 22nd Oct)

	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
Jun-1	38	19	4									
2	38	19	4									
3	38	19	4									
4	27	13	21									
5			39	18	4							
6			39	18	4							
7			34	18	9							
8				12	37	12						
9					37	14	10					
10					37	14	10					
11					11	11	36	3				
12							36	25				
13							36	25				
14							5	32	24			
15								32	29			
16								3	25	17	15	1
17									39	12	6	4
18									9	26	22	4
19									5	26	26	4
20									14	17	26	4
21	38	19	10.8									
22	38	19	10.8									
23	38	19	10.8									

24	27	13	27.8									
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
25			39	18	10.8							
26			39	18	10.8							
27			6.8	18	37	6						
28				12	37	14	4.8					
29					37	14	16.8					
30					6.4	14	36	11.4				
Jul-1						3	36	28.8				
2							36	31.8				
3							3.4	32	18.2	2.8	11.4	
4								16	30	5.8	15	1
5									39	22	2.8	4
6									34.6	15.4	13.8	4
7									11.8	26	26	4
8									11.4	26	26	4
9	38	19	19.2									
10	38	19	19.2									
11	38	19	19.2									
12	27	13	36.2									
13			39	18	19.2							
14			12.2	18	37	9						
15				18	37	14	7.2					
16				12	37	14	13.2					
17					8.8	14	36	17.4				
18							36	32	8.2			
19							36	32	8.2			

20							4.6	32	12.4	0.6	25.6	1
21								6.6	39	24	2.6	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
22									31.4	26	14.8	4
23									20.2	26	26	4
24									25.6	21.4	26	4
25	38	19	24.3									
26	38	19	24.3									
27	38	19	24.3									
28	27	13	39	2.3								
29			33.1	18	30.2							
30				18	37	14	12.3					
31				18	37	14	12.3					
Aug-1				9.7	34.8	14	22.8					
2						9	36	32	4.3			
3							36	32	13.3			
4							13.6	32	34.7			1
5								2.3	30	23.3	21.7	4
6									30	26	21.3	4
7									25.3	26	26	4
8								21.7	7.4	22.7	26	4
9	38	19	36.8									
10	38	19	36.8									
11	38	19	36.8									
12	27	13	34.6	18	1.2							
13				18	37	14	24.8					
14				18	37	14	24.8					

15				12	37	14	30.8					
16					26.8	9	36	22				
17							1.2	32	39	5.2	15.4	1
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
18								25	39	18.8	7	4
19								7	39	18.8	25	4
20								13	28	26	22.8	4
21							15.4	21		26	24.8	4
22	38	19	36.8									
23	38	19	36.8									
24	38	19	36.8									
25	27	13	34.6	18	1.2							
26				18	37	14	24.8					
27				18	37	14	24.8					
28				12	37	14	30.8					
29					26.8	9	36	22				
30							1.2	32	39	5.2	15.4	1
31								25	39	18.8	7	4
Sep-1								7	39	18.8	25	4
2								13	28	26	22.8	4
3							15.4	21		26	24.8	4
4	38	19	30.1									
5	38	19	30.1									
6	38	19	30.1									
7	27	13	39	8.1								
8			15.7	18	37	14	2.4					
9				18	37	14	18.1					

10				18	37	14	18.1					
11				3.9	28	9	36	10.2				
12							36	32	19.1			
13							22.4	18.2	20	11.7	13.8	1
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
14								32	30	10	11.1	4
15								13.8	17.3	26	26	4
16									39	26	18.1	4
17								13.8	19.6	24.3	26	4
18	38	19	24.3									
19	38	19	24.3									
20	38	19	24.3									
21	27	13	39	2.3								
22			33.1	18	30.2							
23				18	37	14	12.3					
24				18	37	14	12.3					
25				9.7	34.8	14	7.4					
26						9	36	32	4.3			
27							36	32	13.3			
28							29	25.7	19.3		25.7	1
29								24	22.3	26	5	4
30									39	26	12.3	4
Oct-1									25.3	26	26	4
2								25.7	21.5	20	26	4
3	38	19	4									
4	38	19	4									
5	38	19	4									

6	27	13	21									
7			39	18	4							
8			39	18	4							
9			34	18	9							
10				12	37	12						
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
11					37	14	10					
12					37	14	10					
13					11	11	36	3				
14							36	25				
15							36	25				
16							5	32	24			
17								32	29			
18								3	25	17	15	1
19									39	12	6	4
20									9	26	22	4
21									5	26	26	4
22									14	17	26	4

Table (2.14): Daily **DURA** Irrigated Areas (in Feddan) for Different Minors, Irrigation period (11th Jun. – 26th Sep.).

	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
Jun-11	38	17.5										
12	38	17.5										
13	38	17.5										
14	27	17.5	11									
15			39	16.5								
16			39	16.5								
17			39	16.5								
18			17	16.5	22							
19					37	14	4.5					
20					37	14	4.5					
21					37	14	4.5					
22					6	9	36	4.5				
23							36	19.5				
24							36	19.5				
25							11.5	32	12			
26								32	23.5			
27								12.5	26.5	4	12.5	
28									30	15	9.5	1
29									30	15	6.5	4
30									10.5	26	15	4
Jul-1									12.5	26	25.5	4
2										12	26	4
3	38	19	19.2									

4	38	19	19.2									
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
5	38	19	19.2									
6	27	13	36.2									
7			39	18	19.2							
8			12.2	18	37	9						
9				18	37	14	7.2					
10				12	37	14	13.2					
11					8.8	14	36	17.4				
12							36	32	8.2			
13							36	32	8.2			
14							4.6	32	12.4	0.6	25.6	1
15								6.6	39	24	2.6	4
16									31.4	26	14.8	4
17									20.2	26	26	4
18									25.6	21.4	26	4
19	38	19	30.1									
20	38	19	30.1									
21	38	19	30.1									
22	27	13	39	8.1								
23			15.7	18	37	14	2.4					
24				18	37	14	18.1					
25				18	37	14	18.1					
26				3.9	28	9	36	10.2				
27							36	32	19.1			
28							22.4	18.2	20	11.7	13.8	1
29								32	30	10	11.1	4

30								13.8	17.3	26	26	4
31									39	26	18.1	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
Aug-1								13.8	19.6	24.3	26	4
2	38	19	39	5.7								
3	38	19	39	5.7								
4	38	19	39	5.7								
5	27	13	28	18	15.7							
6				18	37	14	32.7					
7				12.9	37	14	36	1.8				
8					37	14	36	14.7				
9					12.3	9	28.3	12.1	14	17	8	1
10								32	39	16.7	10	4
11								30	17.1	25.6	25	4
12								20	39	12.7	26	4
13								9.4	35.9	26	26	4
14	38	19	30.1									
15	38	19	30.1									
16	38	19	30.1									
17	27	13	39	8.1								
18			15.7	18	37	14	2.4					
19				18	37	14	18.1					
20				18	37	14	18.1					
21				3.9	28	9	36	10.2				
22							36	32	19.1			
23							22.4	18.2	20	11.7	13.8	1
24								32	30	10	11.1	4

25								13.8	17.3	26	26	4
26									39	26	18.1	4
27								13.8	19.6	24.3	26	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
28	38	19	39	5.7								
29	38	19	39	5.7								
30	38	19	39	5.7								
31	27	13	28	18	15.7							
Sep-1				18	37	14	32.7					
2				12.9	37	14	36	1.8				
3					37	14	36	14.7				
4					12.3	9	28.3	12.1	14	17	8	1
5								32	39	16.7	10	4
6								30	17.1	25.6	15	4
7								20	39	12.7	26	4
8								9.4	35.9	26	26	4
9	38	19	10.8									
10	38	19	10.8									
11	38	19	10.8									
12	27	13	27.8									
13			39	18	10.8							
14			39	18	10.8							
15			6.8	18	37	6						
16				12	37	14	4.8					
17					37	14	16.8					
18					6.4	14	36	11.4				
19						3	36	28.8				

20							36	31.8				
21							3.4	32	18.2	2.8	11.4	
22								16	30	5.8	15	1
23									39	22	2.8	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
24									34.6	15.4	13.8	4
25									11.8	26	26	4
26									11.4	26	26	4

Table (2.15): Daily **COTTON** Irrigated Areas (in Feddans) for Different Minors, Irrigation period (11th Jul. – 31st Jan.).

	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
Jul-11	38	7.2										
12	38	7.2										
13	38	7.2										
14	27	18.2										
15		19	26.2									
16		11.2	34									
17			39	6.2								
18			39	6.2								
19			6.8	18	20.4							
20				18	27.2							
21				17.6	27.6							
22					37	8.2						
23					26.8	14	4.4					
24						14	31.2					
25						14	31.2					
26						0.8	36	8.4				
27							30.2	15				
28								32	13.2			
29								32	13.2			
30								32	13.2			
31								0.6	39	5.6		
Aug-1									39	6.2		
2									27.4	2	14.8	1

3										26	15.2	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
4										26	15.2	4
5										17.4	23.8	4
6										14.8	26	4
7	38	12.8										
8	38	12.8										
9	38	12.9										
10	27	19	4.8									
11		12.5	38.3									
12			39	11.8								
13			39	11.8								
14			23.9	18	8.9							
15				18	32.8							
16				6.4	37	7.4						
17					37	13.8						
18					23.3	14	13.5					
19						14	36	0.8				
20						1.8	36	13				
21							36	14.8				
22							11.5	32	7.3			
23								32	18.8			
24								27.4	23.4			
25									39	11.8		
26									39	10.8		1
27									17.5	4.5	24.8	4
28										26	20.8	4

29										23.4	23.4	4
30										21.5	26	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
31	38	19	19.2									
Sep-1	38	19	19.2									
2	38	19	19.2									
3	27	13	36.2									
4			39	18	19.2							
5			12.2	18	37	9						
6				18	37	14	7.2					
7				12	37	14	13.2					
8					8.8	14	36	17.4				
9							36	32	8.2			
10							36	32	8.2			
11							4.6	32	12.4	0.6	25.6	1
12								6.6	39	24	2.6	4
13									31.4	26	14.8	4
14									20.2	26	26	4
15									25.6	21.4	26	4
16	38	19	36.8									
17	38	19	36.8									
18	38	19	36.8									
19	27	13	34.6	18	1.2							
20				18	37	14	24.8					
21				18	37	14	24.8					
22				12	37	14	30.8					
23					26.8	9	36	22				

24							16.6	32	25.4	14.6	4.2	1
25								10	39	14.8	26	4
26								32	19	26	12.8	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
27								9.8	28	26	26	4
28								14.2	33.6	16.6	26	4
29	38	19	36.8									
30	38	19	36.8									
Oct-1	38	19	36.8									
2	27	13	34.6	18	1.2							
3				18	37	14	24.8					
4				18	37	14	24.8					
5				12	37	14	30.8					
6					26.8	9	36	22				
7							16.6	32	25.4	14.6	4.2	1
8								10	39	14.8	26	4
9								32	19	26	12.8	4
10								9.8	28	26	26	4
11								14.2	33.6	16.6	26	4
12	38	19	39	5.7								
13	38	19	39	5.7								
14	38	19	39	5.7								
15	27	13	28	18	15.7							
16				18	37	14	32.7					
17				12.9	37	14	36	1.8				
18					37	14	36	14.7				
19					12.3	9	28.3	12.1	14	17	8	1

20								32	39	16.7	10	4
21								30	17.1	25.6	25	4
22								20	39	12.7	26	4
23								9.4	35.9	26	26	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
24	38	19	36.8									
25	38	19	36.8									
26	38	19	36.8									
27	27	13	34.6	18	1.2							
28				18	37	14	24.8					
29				18	37	14	24.8					
30				12	37	14	30.8					
31					26.8	9	36	22				
Nov-1							16.6	32	25.4	14.6	4.2	1
2								10	39	14.8	26	4
3								32	19	26	12.8	4
4								9.8	28	26	26	4
5								14.2	33.6	16.6	26	4
6	38	19	24.3									
7	38	19	24.3									
8	38	19	24.3									
9	27	13	39	2.3								
10			33.1	18	30.2							
11				18	37	14	12.3					
12				18	37	14	12.3					
13				9.7	34.8	14	7.4					
14						9	36	32	4.3			

15							36	19.1	10.3	3	12.9	
16							29	25	0.3		26	1
17								15	30	26	6.3	4
18								10	39	17	11.3	4
19								6	32.1	26	13.2	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
20								12.9	29	26	25.3	4
21	38	19	24.3									
22	38	19	24.3									
23	38	19	24.3									
24	27	13	39	2.3								
25			33.1	18	30.2							
26				18	37	14	12.3					
27				18	37	14	12.3					
28				9.7	34.8	14	7.4					
29						9	36	32	4.3			
30							36	19.1	10.3	3	12.9	
Dec-1							29	25	0.3		26	1
2								15	30	26	6.3	4
3								10	39	17	11.3	4
4								6	32.1	26	13.2	4
5								12.9	29	26	25.3	4
6	38	19	24.3									
7	38	19	24.3									
8	38	19	24.3									
9	27	13	39	2.3								
10			33.1	18	30.2							

11				18	37	14	12.3					
12				18	37	14	12.3					
13				9.7	34.8	14	7.4					
14						9	36	32	4.3			
15							36	19.1	10.3	3	12.9	
16							29	25	0.3		26	1
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
17								15	30	26	6.3	4
18								10	39	17	11.3	4
19								6	32.1	26	13.2	4
20								12.9	29	26	25.3	4
21	38	19	1.1									
22	38	19	1.1									
23	38	19	1.1									
24	27	13	18.1									
25			39	18	1.1							
26			39	18	1.1							
27			39	18	1.1							
28			6.6	12	37	2.5						
29					37	14	7.1					
30					37	14	7.1					
31					24.7	14	19.4					
Jan-1						6.5	36	15.6				
2							36	22.1				
3							27.4	30.7				
4								32	26.1			
5								19.6	21.2		17.3	

6									39	18.1		1
7									39	15.1		4
8									2.4	26	25.7	4
9									2.1	26	26	4
10									15.2	12.8	26	4
11	38	19	1.1									
12	38	19	1.1									
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
13	38	19	1.1									
14	27	13	18.1									
15			39	18	1.1							
16			39	18	1.1							
17			39	18	1.1							
18			6.6	12	37	2.5						
19					37	14	7.1					
20					37	14	7.1					
21					24.7	14	19.4					
22						6.5	36	15.6				
23							36	22.1				
24							27.4	30.7				
25								32	26.1			
26								19.6	21.2		17.3	
27									39	18.1		1
28									39	15.1		4
29									2.4	26	25.7	4
30									2.1	26	26	4
31									15.2	12.8	26	4

Table (2.16): Daily **WHEAT** Irrigated Areas (in Feddans) for Different Minors, Irrigation period (11th Oct. – 10th Jan.)

	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
Oct-11	38	12.8										
12	38	12.8										
13	38	12.8										
14	27	19	4.8									
15		12.6	38.2									
16			39	11.8								
17			39	11.8								
18			24	18	8.8							
19				18	32.8							
20				6.4	37	7.4						
21					37	13.8						
22					23.4	14	13.4					
23						14	36					
24						1.8	36					
25							36					
26							11.6	32	7.2			
27								32	18.8			
28								27.4	23.4			
29									39	11.8		
30									21.4	10.8	17.6	1
31									17.6	26	17.2	4

Nov-1										26	20.8	4
2										23.4	23.4	4
3									17.6		26	4
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
4	38	19	14.8									
5	38	19	14.8									
6	38	19	14.8									
7	27	13	31.8									
8			39	18	14.8							
9			29.8	18	24							
10				18	37	14	2.8					
11				12	37	14	8.8					
12					26.2	14	31.6					
13						9	36	26.8				
14							36	32	3		0.8	
15							17.8	32			22	
16								29.2	20	11.6	10	1
17									39	26	2.8	4
18									30	26	11.8	4
19									20.2	26	21.6	4
20									32.8	8.4	26	4
21	38	19	24.3									
22	38	19	24.3									
23	38	19	24.3									
24	27	13	39	2.3								
25			33.1	18	30.2							
26				18	37	14	12.3					

27				18	37	14	12.3					
28				9.7	34.8	14	22.8					
29						9	36	32	4.3			
30							36	32	13.3			
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
Dec-1							13.6	32	34.7			1
2								2.3	30	23.3	21.7	4
3									30	26	21.3	4
4									25.3	26	26	4
5								21.7	7.4	22.7	26	4
6	38	19	24.3									
7	38	19	24.3									
8	38	19	24.3									
9	27	13	39	2.3								
10			33.1	18	30.2							
11				18	37	14	12.3					
12				18	37	14	12.3					
13				9.7	34.8	14	22.8					
14						9	36	32	4.3			
15							36	32	13.3			
16							13.6	32	34.7			1
17								2.3	30	23.3	21.7	4
18									30	26	21.3	4
19									25.3	26	26	4
20								21.7	7.4	22.7	26	4
21	38	19	1.1									
22	38	19	1.1									

23	38	19	1.1									
24	27	13	17									
25			39	18	1.1							
26			39	18	1.1							
27			39	18	1.1							
	Minor 1	Minor 2	Minor 3	Minor 4	Minor 5	Minor 6	Minor 7	Minor 8	Minor 9	Minor 10	Minor 11	Minor 12
28			7.7	12	37	1.4						
29					37	14	7.1					
30					37	14	7.1					
31					24.7	9	24.4					
Jan-1							36	22.1				
2							36	22.1				
3							22.4	32	3.7			
4								32	26.1			
5								11.8	39	7.3		
6									30	7.1	20	1
7									30	20	9.1	4
8									11.2	11.9	26	4
9									5	25.7	23.4	4
10										26	16.5	4

Fig. (2.2)

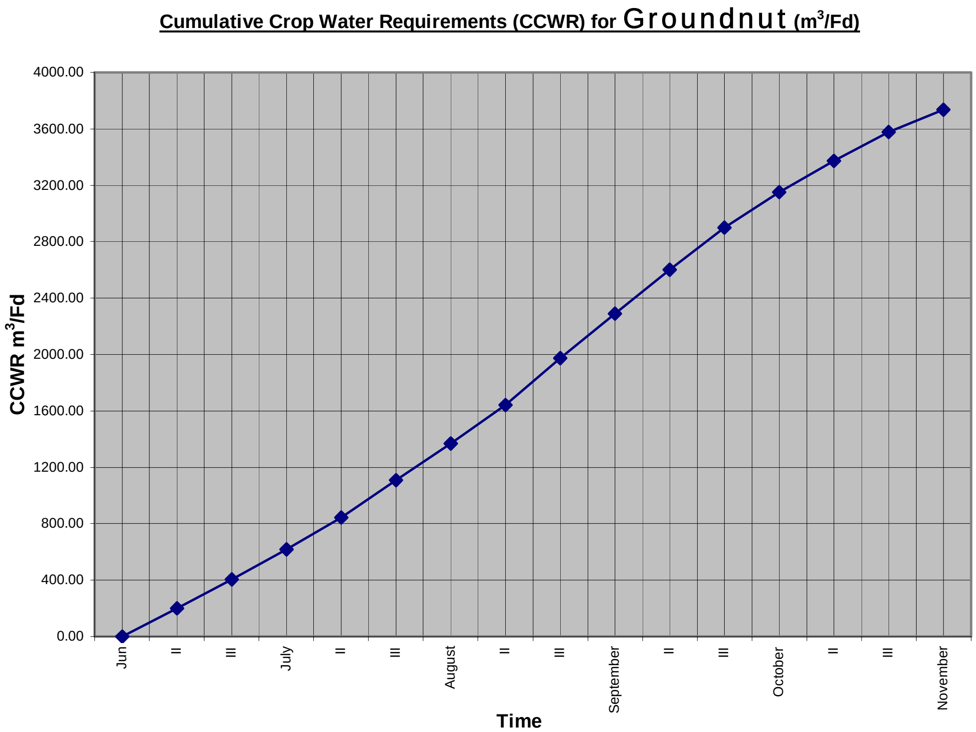
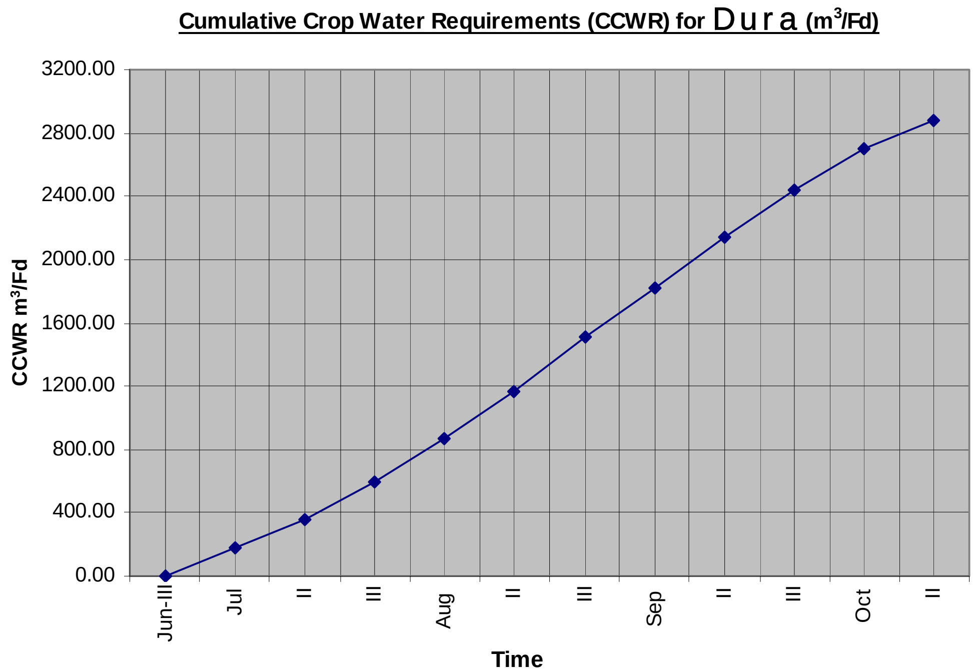
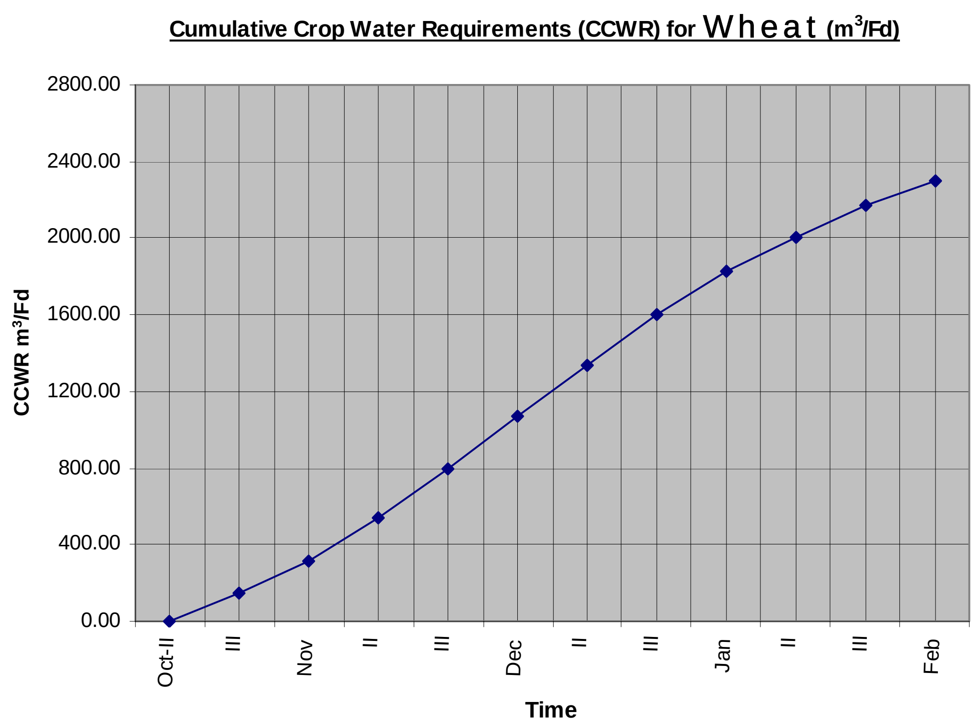

Cumulative Crop Water Requirements (CCWR) for Groundnut (m3/Fd)
CCWR m3/Fd
4000.00
3600.00
3200.00
2800.00
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
Jun
II
III
July
II
III
August
II
III
September
II
III
October
II
III
November
Time

Fig. (2.3)



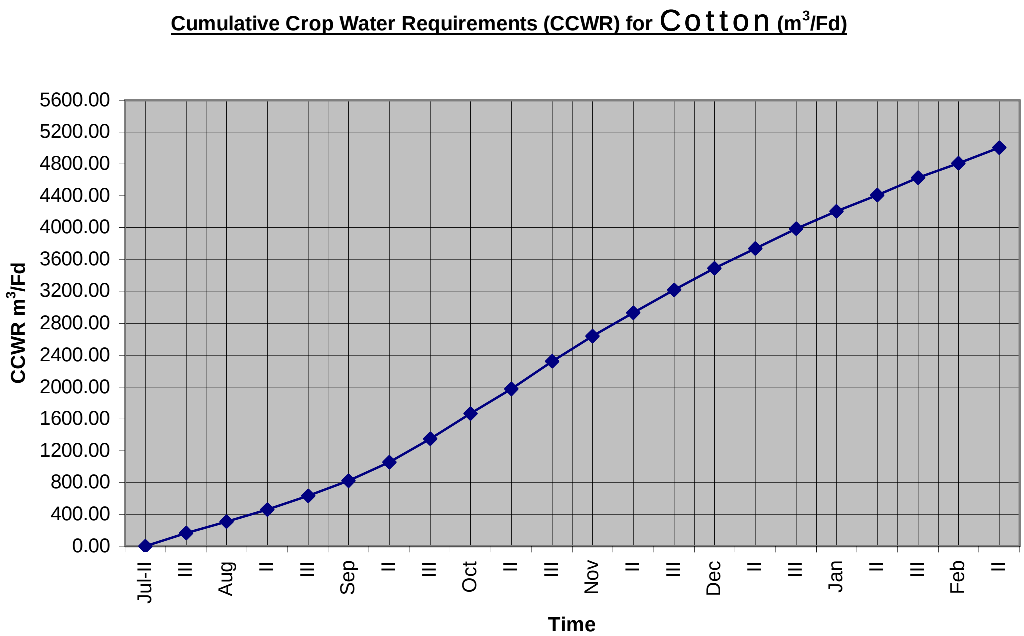
Cumulative Crop Water Requirements (CCWR) for Dura (m3/Fd)
3200.00
2800.00
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
CCWR m3/Fd
Jun-III
Jul
II
III
Aug
II
III
Sep
II
III
Oct
II
Time

Fig. (2.4)



Cumulative Crop Water Requirements (CCWR) for Wheat (m3/Fd)
2800.00
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
CCWR m3/Fd
Oct-II
III
Nov
II
III
Dec
II
III
Jan
II
III
Feb
Time

Fig. (2.5)


Cumulative Crop Water Requirements (CCWR) for Cotton (m3/Fd)
CCWR m3/Fd
5600.00
5200.00
4800.00
4400.00
4000.00
3600.00
3200.00
2800.00
2400.00
2000.00
1600.00
1200.00
800.00
400.00
0.00
Jul-II
III
Aug
II
III
Sep
II
III
Oct
II
III
Nov
II
III
Dec
II
III
Jan
II
III
Feb
II
Time

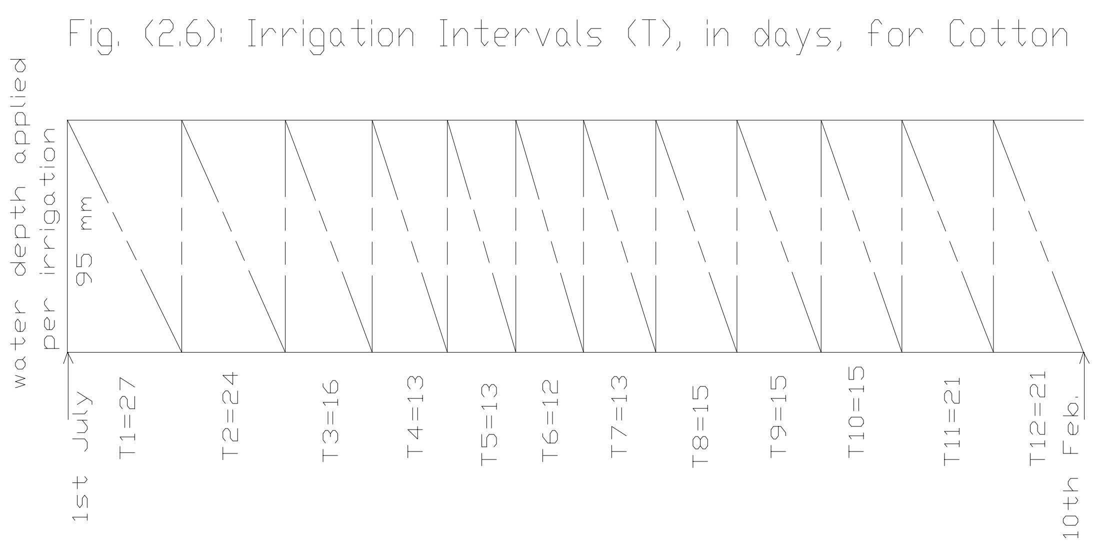


Fig. (2.6): Irrigation Intervals (T), in days, for Cotton
water depth applied per irrigation
95 mm
1st July
T1=27
T2=24
T3=16
T4=13
T5=13
T6=12
T7=13
T8=15
T9=15
T10=15
T11=21
T12=21
10th Feb.

Fig. (2.7): Irrigation Intervals (T), in days, for Groundnut

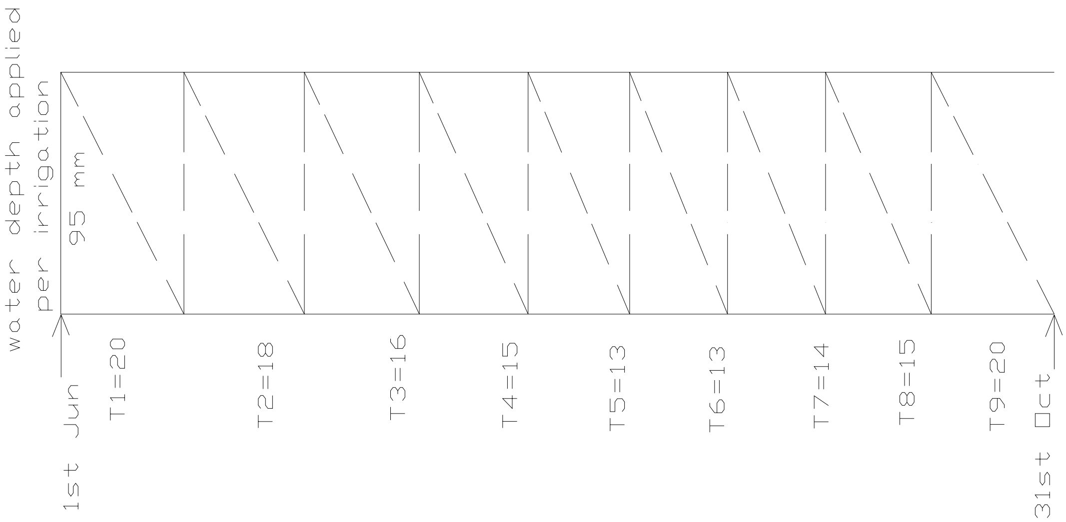


Fig. (2.8): Irrigation Intervals (T), in days, for Wheat

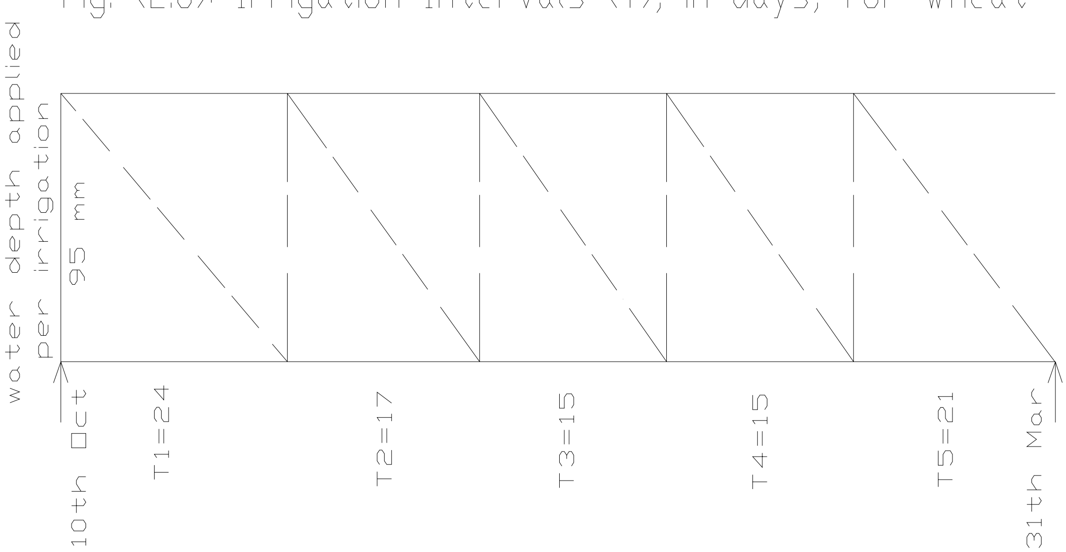


Fig.(2.9): Irrigation Intervals (T), in days, for Dura

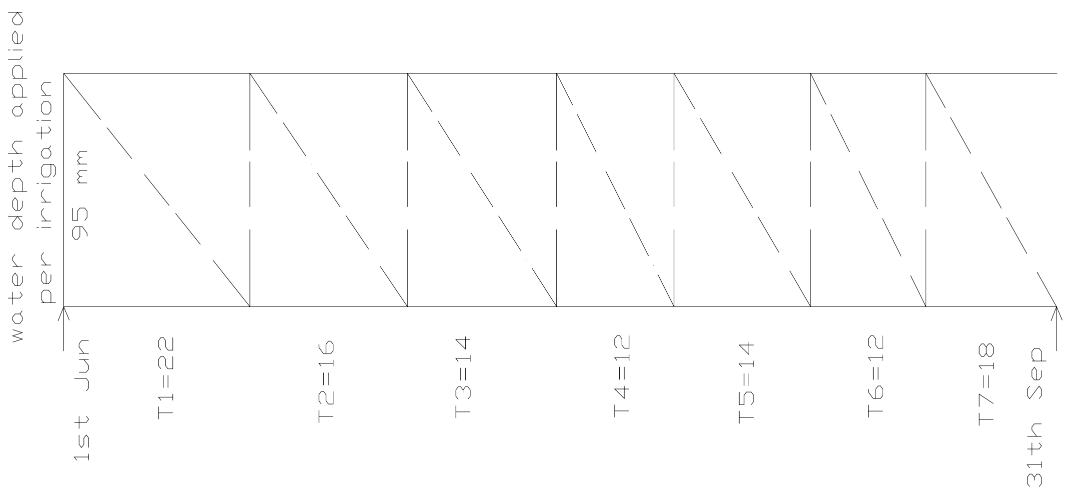
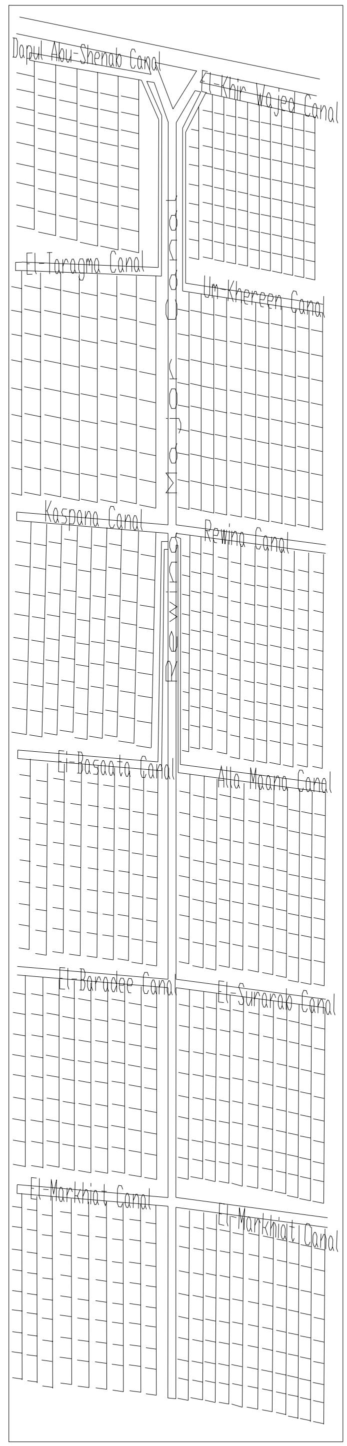


Fig. (2.13): 'Rewina' canal system



Chapter Three

Basic Concepts for Automated Irrigation System

Chapter Three

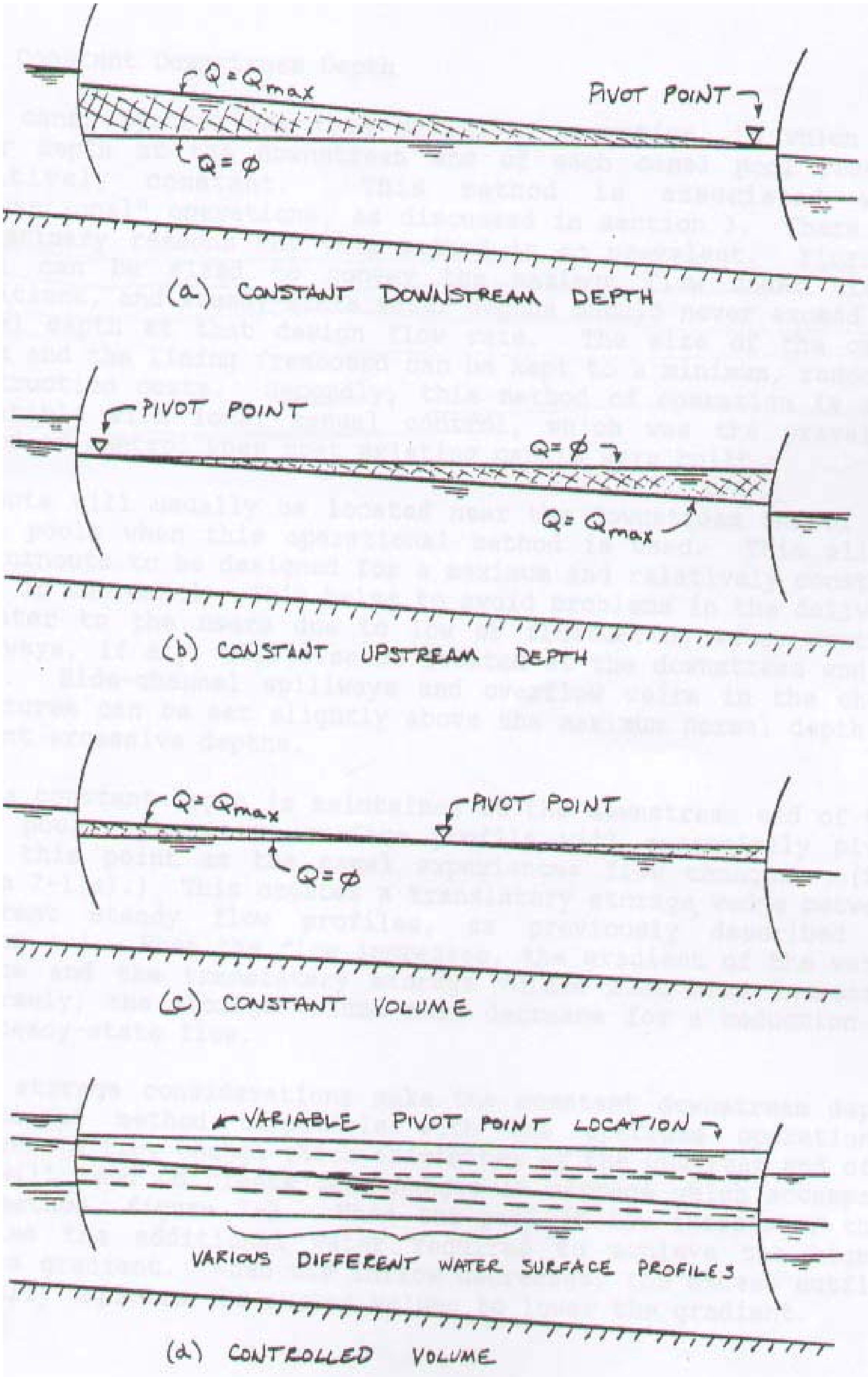
Basic Concepts for Automated Irrigation System

3.1 Operation Methods:

Several methods can be used to transport water downstream through a series of canal pools. These methods used to operate a canal system should not be confused with operational concepts. The operational concept is a matter of priority, whether the downstream demand or the upstream supply is to be satisfied. Whereas, the method of operation determines how the canal pools are operated to satisfy the operational concept. Operational method is tied closely to the check gate operating techniques. The method of operation is based on the location of the canal pool water surface pivot point:

- Constant Downstream Depth: the pivot point is located at the downstream end of the canal pool; figure (3.1a).
- Constant Upstream Depth: the pivot point is located at the upstream end of the canal pool; figure (3.1b).
- Constant Volume: the pivot point is located near the midpoint of the canal pool; figure (3.1c).
- Controlled Volume: the pivot point can move within the canal pool, figure (3.1d).

Fig. (3.1) Operational methods to transport water D/S



3.2 Control Structures:

The operation of a canal system is largely dependent on the location and type of control structures. Operations are primarily affected by the flexibility of adjustment of control structures and by the distance between them.

The most common type of canal control structure is the check structures. Check structures usually contain one or more moveable gates, but sometimes use adjustable weirs or stop logs for control. The increment of adjustment is different with the different types of check structures.

The distance between check structures will have a large impact on the ability to control the flow in a canal. If this distance is large, it will be difficult to make flow changes without causing large depth fluctuations.

Check structure spacing will also influence the responsiveness and stability of a canal system during operations. A smaller distance between checks will usually yield better control. There are no clear-cut criteria for check structure spacing, since the slope and cross-section of a canal factor into this as well.

3.3 Control Concepts:

The control concept is defined by the location of the information needed for control relative to the control structure. This information can include the flow, depth, or volume at one or more points in the canal system, but it is commonly the water depth at a single point in the canal. The two basic control concepts reflect whether this information comes from downstream or upstream of the structure being, as shown in figure (3.2).

Control concepts and operational concepts are very similar, but they are not identical. Operational concepts define the priorities of operation, yet control concepts deal with the actual enactment. Therefore, the relationship between operational and control concepts is a matter of compatibility, as shown in figure (3.3). Only combinations A and D in the figure are compatible.

Fig. (3.2) D/S and U/S control concept

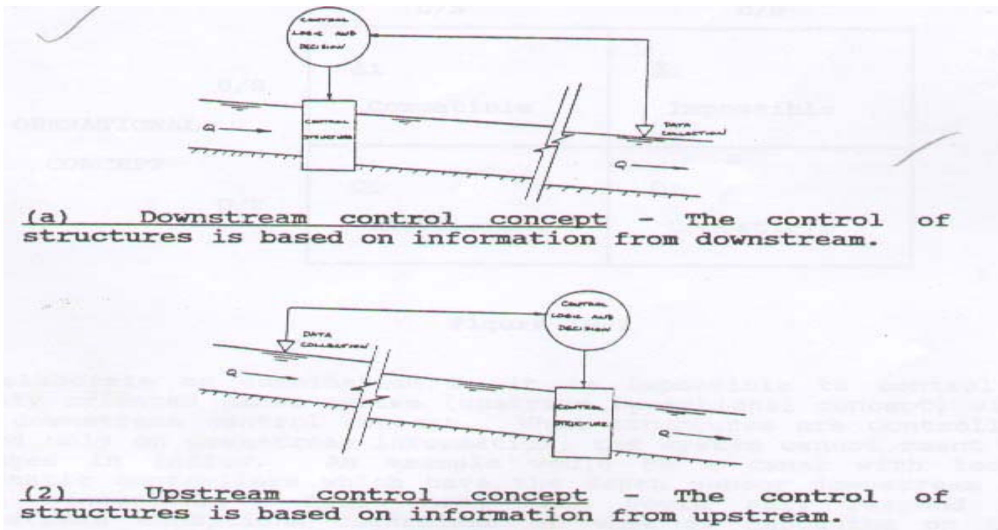


Fig. (3.3) Control concept vs. Operational concept

		CONTROL CONCEPT	
		U/S	D/S
OPERATIONAL CONCEPT	U/S	A: Compatible	B: Impossible
	D/S	C: Inefficient	D: Compatible

To elaborate on combination B, it is impossible to control a supply oriented canal system (upstream operational concept) with the downstream control concept.

When structures are controlled based only on downstream information, the system cannot react to changes in inflow. Each check gate would only respond to downstream conditions regardless of what is happening on the upstream side of the check. If the supply to the canal is lost, due to a pump power failure for example, the upper end of the canal could dewater. Similarly, a rainstorm could increase inflow to the canal through drain inlets, causing excessive depths. In these situations, a shift to upstream control may be required.

3.4 Basic Concept of Irrigation Water Distribution:

3.4.1 Fundamental Rules on Irrigation Water Management:

It is fundamental in irrigation water management to ensure that there is the necessary quantity of water to be distributed impartially among the users. Importance is laid on ensuring water resources from which water can be taken in sufficient quantities for not only meeting the demand for irrigation but also making up conveyance and distribution losses even in water shortage periods.

3.4.2 Conditions of Plentiful Water Resources:

Where water resources are plentiful, water is taken up to the full capacity of facilities and distributed in geometric ratio in accordance with the ratio of the largest quantity necessary in each irrigated region. It is a general rule to "share water impartially" even if there are slight shortages of water.

3.4.3 Conditions of Scarce Water Resources:

As the pressure of water demands increases where water resources are scarce, intake and distribution of irrigation water, need to be kept under proper management through appropriate seasonal control of water intake/distribution facilities. Intake should be limited to the smallest quantity that meets the users' demands in the lower reaches of an irrigation system, and water must be distributed carefully in proportion to demand. Otherwise, it is impossible to satisfy the demand for irrigation water in the whole region.

3.4.4 Water Losses:

In all delivery systems, there are additional water losses through leakage (seepage and evaporation), measurement errors, and poor regulation that must be considered in the capacity determinations. Losses through leakage must be considered for all parts of the system and accumulated in the upstream direction to provide sufficient water downstream. For canals that operate intermittently. However, if the intent of the delivery system is to supply uniform, consistent deliveries, then these losses may be waste, spilled, etc, and upstream reaches may require excess capacity to handle these losses. For systems operating under upstream control with flexible deliveries, these losses are inevitable unless sufficient storage is available to handle, store and reuse this water.

3.5 Check Gate Operating Techniques:

The operation of a canal system is accomplished primarily by controlling the flow through the check structure. Flow changes, which are initiated by gate movements', create the translatory wave phenomenon.

Several canal check gate-operating techniques can be used to change the canal flow and establish a new steady-state flow condition.

The most commonly used techniques are:

- ✓ **Sequential:** each check gate is operated in a progressive order in either the downstream or the upstream direction.
- ✓ **Simultaneous:** all check gates are operated at the same time to quickly change the flow in the entire canal.
- ✓ **Selected:** individual check gates are operated independently of the other checks in the canal.

3.5.1 Sequential:

Operating the canal check gates sequentially, progressing either downstream or upstream, is a technique commonly used to change the canal system flow. This technique is especially compatible with local manual control.

Sequential check gate operation transfers water downstream and flow changes are made at canal side turnouts when the translatory wave arrives.

3.5.2 Simultaneous:

Adjusting all of the canal check gates simultaneously can establish the new steady-state flow in the canal system in the shortest time possible.

The volume of water in the upstream and downstream translatory storage wedges is about equal, so the total volume of water in each canal pool will remain relatively constant for all steady-state flow conditions.

Simultaneous gate operations cannot be accomplished by local manual control unless a ditchrider is stationed at each check gate structure when the flow changes are made. The new gate openings for all the check structures can be transmitted rapidly from a central location, so that all gates are adjusted within one or two minutes of one another.

3-5-3 Selected:

The selected gate operating technique is commonly used to make flow adjustments, which do not necessarily affect the entire canal. Certain check gates may require an adjustment to maintain desired water depths in the adjacent pools. Selected gate operation permits adjustment of water depth and flow within the canal system without having to adjust the head works inflow. This is especially advantageous when the head works consists of a pumping plant where flow increments are limited to the pump unit capacity.

3.6 Supervisory Control and Data Acquisition (SCADA) and Telemetry System:

SCADA system helps the water authority to monitor and control their water system. These systems control the water supply from the dam, through the water treatment stages, to local reservoirs and finally to consumer. Which offer a complete radio telemetry system, including system network design, installation, commissioning, training and servicing. Systems usually consist of greater than 20 sites communicating to a central monitoring computer site. DAS provides comprehensive monitoring and control software packages, RTU hardware, network design and full commissioning, training and maintenance services.

3.7 Data Telemetry and Transmission Systems:

Data telemetry and transmission systems are used to measure, record and transmit hydrological data from recording sites to a central processing site. In some cases, the 'recording' device also carries out an evaluation/analysis of the recorded data at the site. Data may be collected for a range of purposes including flood warning, water resources assessment or operational requirements.

Functions of a data telemetry and transmission system shown in the Table (3.1).

Table (3.1): Data telemetry and transmission system

For example a tipping bucket rain gauge, float well and/or shaft encoder	CONVERSION and/or ENCODING SUB SYSTEM
For example a data logger	(COLLATION/AVERAGE) STORAGE DEVICE
For example telephone or radio telemetry, including the antenna	TRANSMISSION
For example a radio repeater	RELAY
For example a computer at the regional office	RECEPTION

Source (B. J. Stewart, 1998)

3.8 General Sensors Considerations:

Key elements in automated irrigation water delivery systems are the sensors instruments used to measure water levels, flows, gate positions, and the moisture content of the soil. Sensor selection requires consideration of many facets, including accuracy, resolution, repeatability, calibration, temperature effects, maintainability, spare parts availability and cost, vandalism resistance, and position in the technological life cycle.

The level of performance achieved in the operation of automatic systems depends heavily on the accuracy of the data received from the remote sensors. Provisions must be made for some degree of error in the reading values and for the special case of a bad value. The bad value situation is important to consider in automatic systems and procedures must be in place to preclude the system from taking improper action based on bad values. A method recommended in this regard is to have the system computer do data validity checking and flag out of limit values for operator attention.

3.9 Control Gate Openings:

Since control gates are required in canals, an equipment savings advantage can be obtained if flow measurement can be done concurrently. The system computer from sensor inputs of upstream and downstream water levels and gate opening calculates flows per gate.

An advantage of using control gates for measurement also is that the new flow is instantaneously available when the operator is making gates are used for measurement, several minutes can elapse before the new flow value is known.

A disadvantage of gate flow measurement is the inaccuracies frequently experienced at low and high flows. Gate openings in the range of 10 to 50 percent give good measurement results. Free-flow conditions usually give better results than submerged flow conditions. At multiple-gate sites, it is usually possible to work in the desirable measurement range until the total station flow goes above mid-range.

Use of different equations or at least different equation constants for different ranges of flow is a technique with improves measurement accuracy. Derivation of the best equation to use for each range is usually done empirically. This segmentation approach is applicable to measurements by flumes and weirs also.

3.10 Automatic Gate Control System:

This system manages the gate opening and closing versus a sensor automatically to manage water flow to and from watercourses. This system automates and monitored the opening and closing of gates from remote by way of Wide Area Network (WAN). Electronic sensor measures the levels of the water both upstream and downstream and generates water level signal. The signal shall feed to an intelligent controller that shall rise or lower the gates as required. Intelligence incorporated into the gate includes the water levels at which the gate is to operate. Intelligence also incorporated so that a number of gates at different points in the water system can activated at different time so that the Load into rivers can be controlled.

This gates system can be linked to Central Monitoring System (CMS), which allows the monitoring of the flows and levels in the waterways. With this link, we can control the operation of the gate remotely from Central Monitoring System (CMS).

3.11 Water Level Sensors:

Instruments employing floats, bubblers, ultrasonic, and pressure as the sensing method are the four most widely used for measurement of water levels. Each has some strong and weak points to consider when designing the system.

Float Type: The use of floats is perhaps the oldest method and offers several important advantages. It is inherently the least temperature sensitive of the four types. It ranks well in all sensors selection attributes. Conversion of float position to an electronic signal is done in any of several methods, two of the most widely used being potentiometric and shaft position encoders.

Bubblers Type: These devices have been in use for many years and offer the advantage of remaining operable when freezing, or near freezing conditions would cause problems in a stilling well. They are also cheap to install. A disadvantage is their sensitivity to temperature for both the air compressor and the air pressure to electrical signal converter unit. These characteristics can be compensated for; however, in general the accuracy and repeatability are only average.

The air compressor usually requires considerable maintenance or, alternatively, periodic replacement.

Ultrasonic Type: The main advantage of these devices is that there are no moving parts in the equipment and no contact with the water is required. The ultrasonic transmitter unit emits sound waves aimed at the water. These sound waves reflect from the water surface and are picked up by a receiver unit. The time difference between the transmission of the ultrasonic waves and its receipt determines the position of the water surface. Normally a stilling well is used, although reflection from the canal surface will work if reading-to-reading variations can be tolerated. In a stilling well and under constant temperature conditions, good accuracy, resolution and repeatability can be attained.

The temperature sensitivity is the greatest drawback of the ultrasonic units from two aspects. The primary problem is the sensitivity of the electronic circuits to temperature variation. Compensating networks mitigate the effects to a large degree but some error is still present. A secondary effect is due to air temperature variations and the change it causes to the ultrasonic equipment to the water surface, this effect is minor.

Pressure Type: Use of piezoelectric sensors for water level measurement has found a niche where other methods cannot be used for some reason. The sensor is placed at the zero level reference point in the canal whose level is being measured. This makes for a simple and inexpensive installation. No stilling well is required.

Two significant drawbacks are encountered with piezoelectric sensors. The first is that their output signal is at very low levels and must be amplified to be usable. Amplifiers inherently introduce errors into measurement systems. A second drawback is that individual piezoelectric sensors have slightly different response characteristics. Calibration curves and/or compensating networks are necessary and complicate their use considerably.

Another drawback to both the piezoelectric sensor and the signal amplifier is their sensitivity to temperature. In addition, the sensor is subject to fouling in the water. Overall, pressure measurement using piezoelectric sensors to determine water levels requires a degree of sophistication greater than desirable for widespread use.

3.12 Flow Rate Sensors:

Three basic methods are used to measure flows in canals:

1. Instruments that require no canal structures such as ultrasonic flow meters,
2. Structures placed in the canal for measurement purposes such as flumes and weirs, and
3. Obtaining flows based on control gate openings. A common requirement for all three methods is the need for a water level measurement (except for ultrasonic measurement in pipelines). Thus, the comments made in the previous section are applicable as well as the comments to be made in this section about the flow measurement process.

Ultrasonic Flow meter: These devices are used in both pipe and open channel flow measurement. They are more widely used in pipe-line applications, particularly if the pipe is always full; partially full pipes introduce significant measurement problems. Ultrasonic canal flow measurement yields acceptable results under proper conditions. Some items, which cause problems, are debris in the canal such as a heavy silt load. Floating moss and similar aquatic growth also cause errors to occur. Measurement of flows in shallow reaches where the depth is less than three feet (one meter) should not be done.

Ultrasonic flow measurement is done by sending two beams across the canal at an angle, typically 45^0. One beam is with the flow and the other is against the flow. The difference in time for the upstream vs. downstream beams to cross the canal is a measure of the flow velocity. Combining this with the water depth and the canal cross-sectional area yields the flow rate.

The same comments regarding temperature sensitivity made in the previous section on ultrasonic water level sensors apply to ultrasonic flow sensors.

Flumes and Weirs: Both of these types require a structure to be placed across the canal to facilitate the measurement. A concern that arises because of the structure is the head loss in the canal to downstream locations and the higher tail water elevation at upstream locations. Due consideration must be given to what these values are and the effect they will have on canal operation, particularly at low and high flows.

Flumes work on the principle of a geometrically determined constriction through which the water passes. The depth of the water at the input to the flume is measured and inserted into a formula to calculate the flow rate.

Many different types of weirs exist; however, they can be classified into two basic types: sharp crested and broad crested. Sharp crested weirs are extensively used in irrigation projects and are considered quite accurate; however, they require more attention to maintain their accuracy compared to broad crested weirs. In particular, broad crested weirs, which ramp up to the crest, are very reliable with almost no maintenance to the weir structure required. Weirs, which have a vertical rise from the canal floor to the crest, can encounter the problem of silt accumulation in front of the structure. If silt accumulation reduces the distance from the canal floor to the crest so that it is less than twice the depth of the water over the crest, then operational measuring accuracy deteriorates.

3.13 Gate Position Sensors:

There are two aspects to consider concerning the measurement of gate position:

1. The sensing device which converts the gate opening to an electronic signal,
2. The mechanical means by which gate position is coupled to the sensing device.

3.14 Soil Moisture Sensors:

There are many companies that manufacture different kinds of sensors, these sensors are designed for variety of purposes such as:

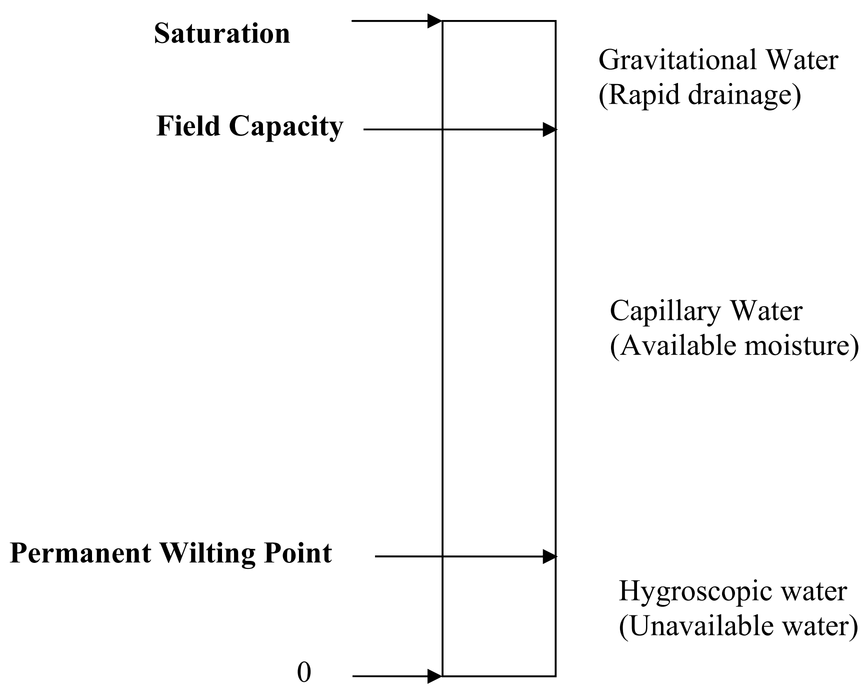
1. Site-specific soil and weather monitoring,
2. Multi-layer moisture readings,
3. Monitoring of water consumption,
4. ET_0 calculations,
5. Reliable wireless data transfer,
6. Crop specific irrigation monitoring, and

7. Accurate irrigation control.

Advantages of these sensors are:

1. Optimize irrigation management,
2. Improve yield and quality,
3. Increase profitability, and
4. Cable-free soil moisture monitoring.

3.15 Classes and Availability of Soil Water:



3.15.1 Field Capacity:

In practice (MOIWE, Report) field capacity is measured after 2-days, when gravitational water has been removed the moisture content of the soil is called field capacity.

3.15.2 Permanent Wilting Point (PWP):

The permanent wilting point is the soil moisture when the plants permanently wilt.

3.16 Sensing Devices:

The oldest types of sensing devices used to convert the gate's, in terms of use, employs the potentiometric principle. A mechanically controlled, variable resistor has either a voltage impressed across it or a current passed through it. The resistance varies proportionally to the gate position so the output voltage or current from the variable tap on the resistor then represents gate position.

There are two types of shaft position encoders. The simplest type uses a code wheel, which is a single track of alternating translucent and opaque sections. As the code wheel rotates, the light sensor detects and counts the number of transitions from light to dark. Each transition pulse represents an increment of gate movement, thus the number in the counter represents the gate opening. This type is called a pulse counting shaft position encoder.

The second type is called an absolute shaft position encoder. It functions similarly except that its code wheel has several tracks instead of just one. Each succeeding track has twice as many translucent and opaque sections as the previous one. Each succeeding track has twice as many translucent and opaque sections.

3.17 Sensor Interfaces:

As part of system operation, the output signal from the sensors must be telemetered to the digital computer at the central station. The signal must be in a digital form by the time it is input to the computer. The conversion from analog to digital can occur at one of three points in the system:

1. at the sensor,
2. at the remote site central electronics, or
3. at the central station prior to input to the computer.

There are tradeoffs to consider in deciding at which point the conversion should occur, the major one being cost vs. accuracy. In general, analog instruments are less expensive than digital ones and provide sufficient accuracy in many cases. Analog signals, however, suffer from interference, power supply drift, telemetry degradation and other similar problems, which can result in data of lesser accuracy than from a digital system. Once digitized, signals representing measurement values lose no accuracy from thereon in the data path.

A system with sensors providing digital output signals gives the best result because transmission induced errors are eliminated as closed to the source as possible. A system that is less costly uses analog sensors and converts their output to digital in the remote site central electronics before being telemetered to the central station. Fairly good results are usually obtained, absent any long instrumentation cable runs or significant electrical interference problems. The least used system configuration is to telemeter analog signals from the remote sites and convert to digital at the central station. This approach can be less costly; however, it results in the lowest accuracy of the three methods.

3.18 Gates to Sensing Device Linkage:

There are several variables to consider regarding the linkage, which couples the gate to the sensing device:

1. type of gate – vertical or radial,
2. gate operating method – hoist cables or gear assembly, and
3. gate position take-off and coupling means – direct or scaled and gears or cable.

Type of Gate: vertical gates offer the advantage of providing gate opening as a linear functions whereas for radial gates, it is a cosine function. Vertical gates are subject to binding against their slides, especially under large heads of water.

Gate Operating Method: the two methods employed to operate gates are gear assemblies and hoist cables. Either type can be used on either gate type. The most frequent occurrence is gears on vertical gates and hoist cables on radial gates.

Gate Position Takeoff and Coupling Means: the point at which the gate motion is picked-off can provide a direct 1:1 travel ratio or be at some scaled down ratio.

3.19 Equipment and Operating of Dynamic Regulation:

Dynamic regulation makes use of operating procedures and associated equipment apparatus, which is widely available in process, automated control and, especially:

- data acquisition,
- data transmission,
- data processing and remote control.

a. *Data Acquisition:*

The data required consists of measurements of physical parameters (levels, discharges, pressures, gate positions) and indications of status (on/off, alarm).

Water levels are measurements by means of float sensors and electromagnetic, ultrasonic are used to measure discharge.

Pressure measurements are taken by means of mechanical or electrical differential pressure gages.

Volume is measured by integrating water level and flow measurement.

b. Data Transmission:

Due to the physical characteristics of the hydraulic network, the statutory requirements and reliability, an all-cable transmission system has been adopted.

A dual network is used which comprises transmission cables laid alongside the hydraulic installations and links via the public telecommunications network.

The control center can contact any outlying station along two separate routes; should there be a break on one channel, the other will ensure the link.

c. Data Processing and Remote Control:

The functions of acquisition and processing data and gates and pumping control are carried out in real-time by means of a series of programs, which constitutes the software of the dynamic regulation process. These programs use pre-calculated data and results from hydraulic computations.

3.20 Diversion Facilities and Automatic Control:

a. Opening and Closing:

The opening and closing of the gate of a turnout can be shifted from manual operation on the spot to electric control in the operation room. At first, on-off switching is conducted through the monitoring of openings. Then, opening of gates are adjusted in accordance with prescriptions, and later, opening and closing are automatically controlled, by setting the quantity of water to be diverged and finding the required openings through calculation (SCADA software).

b. Check Gate:

A check gate is constructed for keeping the level of water constant in the main canal for ensuring stable diversion in proportion to openings. Check gates are classified into those, which keep the level of water constant by means of the linkage of water level measurement and the control of openings.

c. Opening Setting:

Methods of finding adequate openings from prescribed quantities of diversion water include the method in which openings are adjusted through measuring the water level of the main canal and calculating the necessary opening. Another method uses a feedback mechanism, in which the water level in the lower reaches is measured by calculating the quantity of diversion water, and the opening is readjusted, based on the difference from the prescribed quantity. Both methods are based on the assumption that the flow of water is steady at the time of water level measurement. If the flow is not steady, it is possible to adjust openings by unsteady flow analysis based on water levels and their changes in the upper and the lower courses. It is, however, difficult to carry out a stable control.

d. *Automatic Control System:*

An automatic irrigation water control system refers to an apparatus, which automatically carries out measurement, calculation, control and regulation over the full range of the irrigation scheme from the water source to the fields, by utilizing technologies of telemetry, tele-control, data transmission and remote regulation of gates and other control facilities.

3.21 Operating Software:

The operating software required to direct the process of water control is a critical item in the successful implementation and acceptance of the automated control system. The task of the designer is to translate the operational desires of the ditchrider and water master into automated actions in the field. This is sometimes a complex task for two main reasons:

The first reason is the slow response time and the significant inertia in the conveyance system as compared to other processes. Wave action in canals can constitute large variations in instantaneous levels signals.

The flexibility of the PLC allows the development of software to alleviate these problems. The software in the controller does extensive averaging of gate position and level inputs. All the control logic uses the averaged values of the input signals. This avoids spurious gate movements due to fluctuating input signals.

The slow response in the process has led to the incorporation of feed-forward control in addition to conventional feedback control. Feed-forward control is used to make initial gate changes based on an estimation of the required increment. Feedback control fine-tunes the gate positions after the process reacts to the initial gate change. Rather than wait for the entire change to become stable prior to fine-tuning, the controller monitors the change as it occurs. In this manner, the controller can react sooner if the process is not responding with the expected results.

The second reason for difficulty in writing successful operating software relates to the operators. In many cases the operating staff has no previous exposure to the technology that is being proposed for the control system, and in the extreme, they have little exposure to mechanization. This situation has led to the need for more sophisticated hardware and software to act as the interface between the operators and the control system.

In addition to the reporting functions, the communications controller acts as the intermediary between the operator and the process. The operator submits control changes to the controller, which converts them to operating instructions for the PLC.

3.22 Canal Automation System:

a. Hardware:

In the past, application of canal automation has been hampered by incompatibility of system components. A significant effort is required when specifying each component in order to insure compatibility. Remote operation required considerable hardware modification in order to function at even a rudimentary level. Typical hardware components for canal automation systems are shown below:

Table (3.2): Hardware components for canal automation

Hardware supplied by automata	Hardware from other suppliers
Water level sensors	Gate
Gate position sensors	Gate lifting gears
Gate motor control circuitry	Gate motor &control relays
Remote terminal unit (RTU)	Gate motor limit switches
Communications system	Central computer with peripheral devices

(Reference, ASCE 1987)

b. Software:

Compatibility is also required among the various logical component of the control system. The feedback, and flow control logic must be compatible &with appropriate transfer of information between them. For many systems, control actions should be recorded &archived, whether manual for automatic. These requirements suggest the need to embed these control functions within commercially available SCADA (Supervisory Control and Data Acquisition) packages. Many water districts already use SCADA systems. Software components for automatic control systems are shown in table below.

Table (3.3): Software components for automatic control systems

RTU logic	Communications	Central computer logic
Sensor analysis	Type	Closed-loop control from remote site feedback
Gate control	Protocol	Open-loop control from known changes
Closed loop control	Baud rate	Coordination with supervisory control operator
	Etc	Interface with supervisory control operators
		Interface with water ordering system
		Interface with water accounting system

(Reference, ASCE 1987)

Chapter Four

Towards Automation of Rewina Canal System

Chapter Four

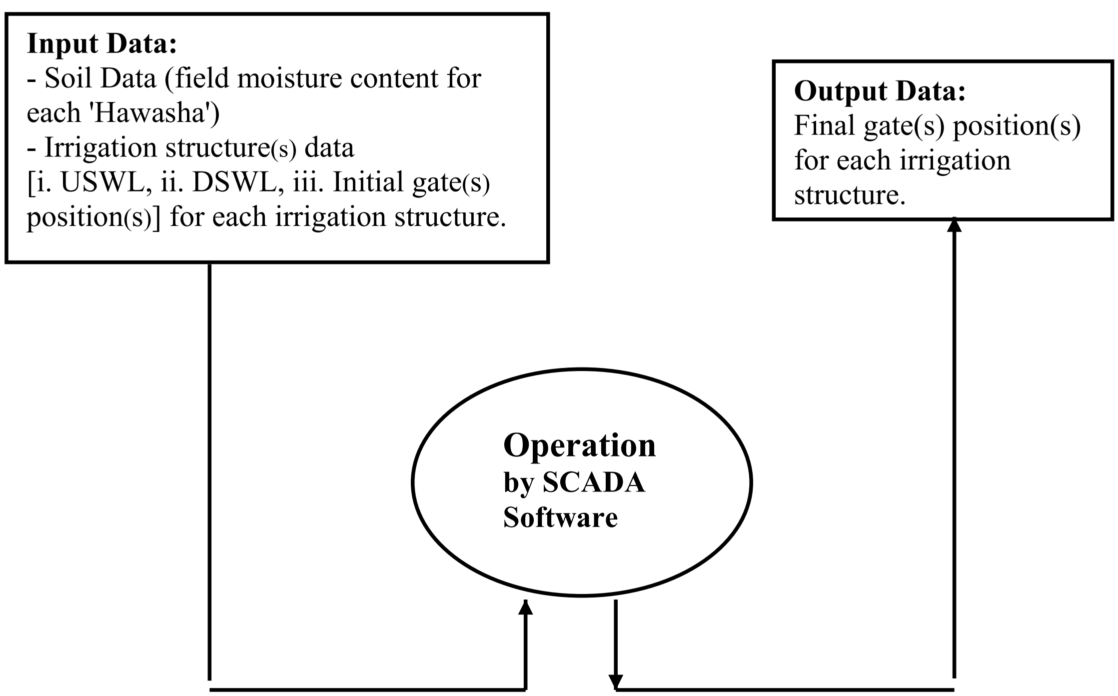
Towards Automation of 'Rewina' Canal System

4.1 Automation of 'Rewina' Canal:

Theoretically, automation technology has been utilized on 'Rewina' Canal System for better control and operation.

Input data (monitored by sensors) that is required for automatic irrigation system consists of soil data and irrigation structures data, which can be analyzed in the central control room to determine the total area that will be irrigated on daily basis, discharges required, number of structures to be operated to pass the required discharges, and the irrigation structure(s) data as it illustrate in Figure (4.1).

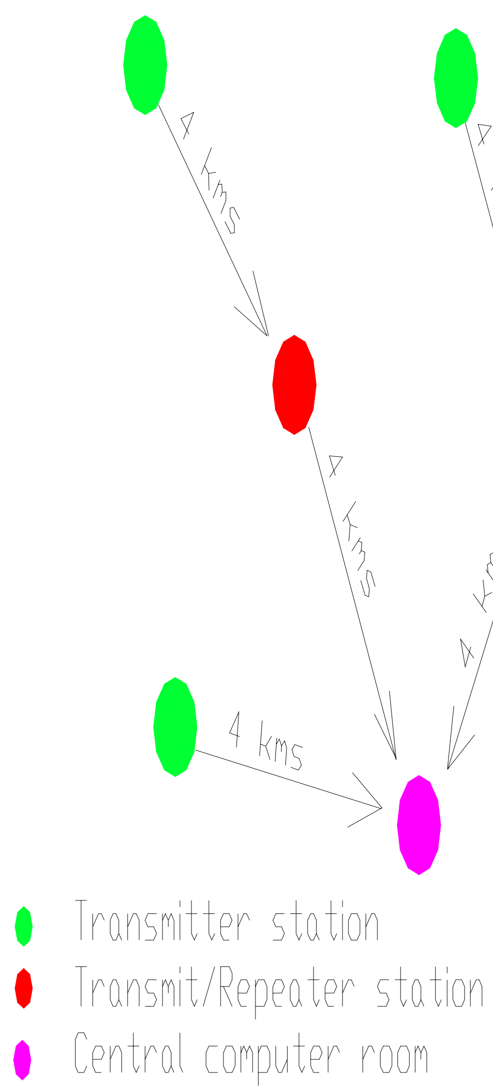
Fig. (4.1): Software procedure



4.2 Project Telecommunication System:

Distances between sensors and repeater will have a large impact on the ability to send, receive and strengthen the signals. The maximum distance to receive the signal is shown in Figure (4.2).

Fig. (4.2): Transmitter / Repeater station location



4.3 Mechanism of Gate Opening:

The equation that govern the passing discharge through the gates structure is

$$\mathbf{Q = C\ a_0\ h^{1/2}} \qquad \text{----------------------- (4.1)}$$

Where:

Q: Passing discharge (m^3/sec).

C: Constant (= 3.0).

a_0: Gate opening in m^2.

h: Difference in head in m.

x: Distance equivalent to gate opening area (a_0) in m.

Case (i): ($0 < \Theta < 180^0$)

Figure (4.3) shows the area of gate opening incase the opening degree is greater than 0^0 and less than 180^0.

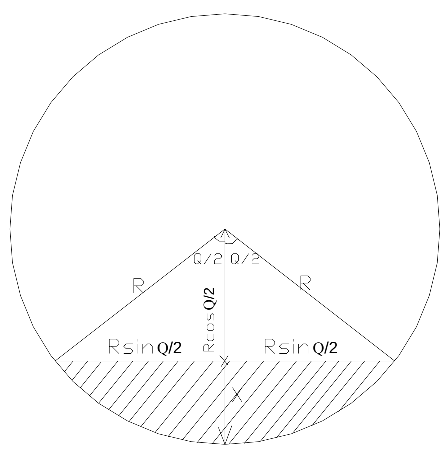


Fig. (4.3), (0° <Q <180°)

a_t: max. gate opening

a_0: shaded area

$$\mathbf{a_t = \prod R^2}$$

$$\mathbf{[a_t]_\Theta = \prod R^2 (\Theta/360)}$$

$$a_0 = [a_t] - 0.5\,(2\,R\,(\sin\Theta/2))\,R\,(\cos\Theta/2)$$

$$= \prod R^2 (\Theta/360) - R^2 \sin(\Theta/2)\cos(\Theta/2)$$

$$a_0 = R^2\,((\prod\Theta/360) - 0.5\sin\Theta)$$

$$X = R - R\cos\Theta/2$$

$$a_0 = R2\,((\prod\Theta/360) - 0.5\sin\Theta) \quad \text{-------------------} \quad (4.2)$$

$$X = R - R\cos\Theta/2 \quad \text{-------------------} \quad (4.3)$$

Case (ii): ($180^0 < \Theta < 360^0$)

Figure (2.15) shows the area of gate opening incase the opening degree is greater than 180^0 and less than 360^0.

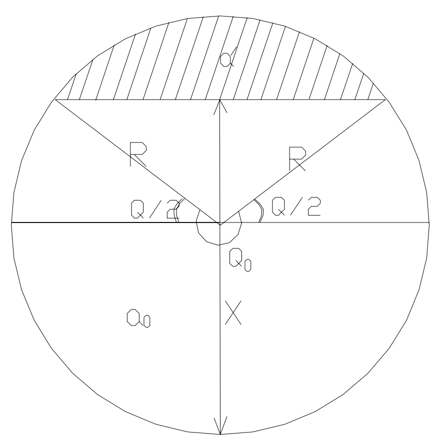


Fig. (4.4), (180°<Q<360°)

$$a_0 = \prod R^2 - a'$$

$$= \prod R^2 - [\prod R^2 ((180+\Theta)/360) + (R\cos(\Theta/2))\,(R\sin(\Theta/2))]$$

$$X = R + R\sin(\Theta/2)$$

$$a_0 = R^2\,[\prod - \prod((180+\Theta)/360) + 0.5\sin\Theta]$$

$$a_0 = \prod R^2 - \prod R^2((180+\Theta)/360) + 0.5R^2\sin\Theta$$

$x \quad = R + R \sin\Theta/2$

$$\mathbf{a_0 = \prod R2(1-(\Theta+180)/360) + 0.5\ R2 \sin\Theta)} \quad \text{---------------} \quad \mathbf{(4.4)}$$

$$\mathbf{X = R + R \sin\Theta/2} \quad \text{--------------} \quad \mathbf{(4.5)}$$

Table (4.1): Area of gate opening (a_0) as a function of depth of gate opening (x), for pipes diameters (35cm, 50cm and 76cm)

Dia. = 35 cm	**Dia. = 50 Cm**	**Dia. = 76 cm**

R	= 17.5	cm	R	= 25	cm	R	= 38	cm
a_0	x	Θ	a_0	X	Θ	a_0	x	Θ
0.005	1.75	51.68	0.01	2.5	51.68	0.02	3.3	48.11
0.010	3.50	73.74	0.02	5.0	73.74	0.04	6.6	68.56
0.015	5.25	91.15	0.03	7.5	91.15	0.06	9.9	84.63
0.020	7.00	106.26	0.04	10.0	106.26	0.08	13.2	98.52
0.025	8.75	120.00	0.05	12.5	120.00	0.10	16.5	111.09
0.030	10.50	132.84	0.06	15.0	132.84	0.12	19.8	122.77
0.035	12.25	145.08	0.07	17.5	145.08	0.14	23.1	133.83
0.040	14.00	156.93	0.08	20.0	156.93	0.16	26.4	144.45
0.045	15.75	168.52	0.09	22.5	168.52	0.18	29.7	154.77
0.050	17.50	180.00	0.10	25.0	180.00	0.20	33.0	164.88
0.055	19.25	11.48	0.11	27.5	11.48	0.22	36.3	174.87
0.060	21.00	23.07	0.12	30.0	23.07	0.24	39.6	4.83
0.065	22.75	34.90	0.13	32.5	34.90	0.26	42.9	14.82
0.070	24.50	47.16	0.14	35.0	47.16	0.28	46.2	24.92
0.075	26.25	60.00	0.15	37.5	60.00	0.30	49.5	35.23
0.080	28.00	73.74	0.16	40.0	73.74	0.32	52.8	45.84
0.085	29.75	88.85	0.17	42.5	88.85	0.34	56.1	56.89
0.090	31.50	106.26	0.18	45.0	106.26	0.36	59.4	68.55
0.095	33.25	128.32	0.19	47.5	128.32	0.38	62.7	81.08
0.096	35.00	180.00	0.20	50.0	180.00	0.40	66.0	94.93
Dia. R	= 35 = 17.5	cm cm	Dia. R	= 50 = 25	Cm cm	Dia. R	= 76 = 38	cm cm
a_0	x	Θ	a_0	X	Θ	a_0	x	Θ

						0.42	69.3	110.91
						0.44	72.6	131.16
						0.453	76	360

Table (4.2): Area of gate opening (a_0) as a function of depth of gate opening (x), for pipes diameters (91cm, 101cm, and 124cm)

Dia. **R**	**=91** **= 45.5**	**cm** **cm**	**Dia.** **R**	**=101** **= 50.5**	**cm** **cm**	**Dia.** **R**	**=124** **= 62**	**cm** **cm**
A_0	x	Θ	a_0	X	Θ	a_0	x	Θ
0.02	2.76	40.12	0.04	4.81	50.42	0.04	4	41.39
0.04	5.52	57.03	0.08	9.62	71.90	0.08	8	58.86
0.06	8.28	70.22	0.12	14.43	88.84	0.12	12	72.50
0.08	11.04	81.54	0.16	19.24	103.51	0.16	16	84.21
0.10	13.80	91.67	0.20	24.05	116.83	0.20	20	94.72
0.12	16.56	101.01	0.24	28.86	129.25	0.24	24	104.40
0.14	19.32	109.75	0.28	33.67	141.07	0.28	28	113.49
0.16	22.08	118.04	0.32	38.48	152.46	0.32	32	122.12
0.18	24.84	125.99	0.36	43.29	163.58	0.36	36	130.41
0.20	27.60	133.67	0.40	48.10	174.55	0.40	40	138.43
0.22	30.36	141.13	0.40	52.91	5.47	0.44	44	146.25
0.24	33.12	148.42	0.48	57.72	16.44	0.48	48	153.90
0.26	35.88	155.59	0.52	62.53	27.56	0.52	52	161.44
0.28	38.64	162.66	0.56	67.34	38.96	0.56	56	168.89
Dia. R	=91 = 45.5	cm cm	Dia. R	=101 = 50.5	Cm cm	Dia. R	=124 = 62	cm cm

A_0	x	ϴ	a_0	X	ϴ	a_0	x	ϴ
0.30	41.40	169.66	0.60	72.15	50.77	0.60	60	176.30
0.32	44.16	176.62	0.64	76.96	63.20	0.64	64	3.70
0.34	46.92	3.58	0.68	81.77	76.52	0.68	68	11.11
0.36	49.68	10.54	0.72	86.58	91.20	0.72	72	18.56
0.38	52.44	17.55	0.76	91.39	108.13	0.76	76	26.10
0.40	55.20	24.62	0.80	96.20	129.63	0.80	80	33.76
0.42	57.96	31.79	0.801	101.0	180	0.84	84	41.57
0.44	60.72	39.09				0.88	88	49.59
0.46	63.48	46.55				0.92	92	57.88
0.48	66.24	54.24				0.96	96	66.51
0.50	69.00	62.19				1.00	100	75.60
0.52	71.76	70.50				1.04	104	85.28
0.54	74.52	79.26				1.08	108	95.79
0.56	77.28	88.61				1.12	112	107.50
0.58	80.04	98.77				1.16	116	121.14
0.60	82.80	110.13				1.20	120	138.61
0.62	85.56	123.39				1.205	124	180.00
0.64	88.32	140.47						
0.65	91.00	180.00						

4.4 Automation of 'Rewina' canal system:

1. Input Data

The input data that required for the automation process is illustrated below:

Input Data

Soil Data
(Field moisture content for each 'Hawasha')

USWL, DSWL, Initial Gate(s) position(s) for each irrigation structure

	Area to be irrigated per day			
	Major canal	Minor-1	Minor-2	Minor-3
Jun-1	61	38	19	4
Jun-2	61	38	19	4
Jun-3	61	38	19	4
June-4	61	27	13	21
Jul-9	76.2	38	19	19.2
Jul-10	76.2	38	19	19.2
Jul-11	76.2	38	19	19.2
Jul-12	76.2	27	13	36.2
Oct-3	61	38	19	4
Oct-4	61	38	19	4

Water Head (m)			
Major canal	Minor-1	Minor-2	Minor-3
0.60	0.58	0.56	0.25
0.61	0.57	0.56	0.25
0.62	0.59	0.58	0.25
0.63	0.62	0.60	0.61
0.63	0.61	0.61	0.60
0.62	0.61	0.62	0.59
0.63	0.60	0.61	0.60
0.64	0.59	0.60	0.61
0.64	0.60	0.61	0.62
0.63	0.58	0.57	0.25

Initial gate position (cm)			
Major canal	Minor-1	Minor-2	Minor-3
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

2. Output Data:

The result of the automation process is obtained from SCADA software as a signal to the sensor that fixed on each gate to execute the required opening, which is shown below:

Output Data

	Final Gate(s) Position(s) (cm) for each irrigation structure			
	Major canal	Minor-1	Minor-2	Minor-3
Jun-1	6.60	12.60	7.60	3.30
Jun-2	6.90	12.42	8.25	3.30
Jun-3	6.90	12.42	8.25	3.30
June-4	6.90	8.28	4.95	8.25
Jul-9	8.28	12.42	6.60	8.25
Jul-10	8.28	12.42	6.60	8.25
Jul-11	8.28	12.42	6.60	8.25
Jul-12	8.28	8.28	4.95	13.20
Oct-3	6.90	12.42	6.60	3.30
Oct-4	6.90	12.42	8.25	3.30
Oct-5	6.90	12.42	8.25	3.30
Oct-6	6.90	8.28	4.95	8.25

Sample of Calculation:

To describe the obtained output data by using automation, we take the input data is taken for three days in month June.

June-1:

First, to find the passing discharge through each gate for one major canal and three minor canals, for example, we use the following equation is used:

$Q_{major} = 61*400/0.85 = 28,706\ m^3/day$

i.e. $Q_{major} = 28,706/3 = 9,569\ m^3/day = 0.111\ m^3/sec$

$Q_{minor-1} = 38*400/0.85 = 17,882\ m^3/day = 0.207\ m^3/sec$

$Q_{minor-2} = 19*400/0.85 = 8,941\ m^3/day = 0.103\ m^3/sec$

$Q_{minor-3} = 4*400/0.85 = 1,882\ m^3/day = 0.022\ m^3/sec$

Second, to find the area of gate opening for each gate, the following equation is used:

$\mathbf{Q = c\ a_0\ h^{1/2}, \quad c = 3}$

For the major, $a_0 = Q_{major} / (3 * h^{1/2}) = 0.111 / (3 * 0.60^{1/2}) = 0.048\ m^2$

For minor-1, $a_0 = Q_{minor-1} / (3 * h^{1/2}) = 0.207 / (3 * 0.58^{1/2}) = 0.091\ m^2$

For minor-2, $a_0 = Q_{minor-2} / (3 * h^{1/2}) = 0.103 / (3 * 0.56^{1/2}) = 0.046\ m^2$

For minor-3, $a_0 = Q_{minor-3} / (3 * h^{1/2}) = 0.022 / (3 * 0.25^{1/2}) = 0.02\ m^2$

Using the above data, the final gate(s) position(s), will be obtained by using Tables (4.1), (4.2).

Table (4.3), Final gate position in June-1:

	Gate opening	Calculated gate	Initial gate	Final gate

	a_0 (m^2)	position x (cm)	position (cm)	position (cm)
Major canal	0.048	6.60	0	6.60
Minor-1	0.091	12.60	0	12.60
Minor-2	0.046	7.60	0	7.60
Minor-3	0.02	3.30	0	3.30

June-2:

Q_{major} = 61*400/0.85 = 28,706 m^3/day

i.e. Q_{major} = 28,706/3 = 9,569 m^3/day = 0.111 m^3/sec

$Q_{minor-1}$ = 38*400/0.85 = 17,882 m^3/day = 0.207 m^3/sec

$Q_{minor-2}$ = 19*400/0.85 = 8,941 m^3/day = 0.103 m^3/sec

$Q_{minor-3}$ = 4*400/0.85 = 1,882 m^3/day = 0.022 m^3/sec

$Q = c\ a_0\ h^{1/2}$, $c = 3$

For the major, $a_0 = Q_{major} / (3 * h^{1/2}) = 0.111 / (3 * 0.61^{1/2}) = 0.05\ m^2$

For minor-1, $a_0 = Q_{minor-1} / (3 * h^{1/2}) = 0.207 / (3 * 0.57^{1/2}) = 0.09\ m^2$

For minor-2, $a_0 = Q_{minor-2} / (3 * h^{1/2}) = 0.103 / (3 * 0.56^{1/2}) = 0.046\ m^2$

For minor-3, $a_0 = Q_{minor-3} / (3 * h^{1/2}) = 0.022 / (3 * 0.25^{1/2}) = 0.02\ m^2$

Using the above data the final gate(s) position(s) will be obtained using Tables (4.1), (4.2).

Table (4.4), Final gate position in June-2

	Gate opening [a_0 (m^2)]	Calculated gate position x (cm)	Initial gate position (cm)	Final gate position (cm)
Major canal	0.05	6.90	0	6.90
Minor-1	0.09	12.42	0	12.42
Minor-2	0.046	8.25	0	8.25
Minor-3	0.02	3.30	0	3.30

June-3:

Q_{major} = 61*400/0.85 = 28,706 m^3/day

i.e. Q_{major} = 28,706/3 = 9,569 m^3/day = 0.111 m^3/sec

$Q_{minor-1}$ = 38*400/0.85 = 17,882 m^3/day = 0.207 m^3/sec

$Q_{minor-2}$ = 19*400/0.85 = 8,941 m^3/day = 0.103 m^3/sec

$Q_{minor-3}$ = 4*400/0.85 = 1,882 m^3/day = 0.022 m^3/sec

$\mathbf{Q = c\ a_0\ h^{1/2}}$**, c = 3**

For the major, $a_0 = Q_{major} / (3 * h^{1/2}) = 0.111 / (3 * 0.62^{1/2}) = 0.05\ m^2$

For minor-1, $a_0 = Q_{minor-1} / (3 * h^{1/2}) = 0.207 / (3 * 0.59^{1/2}) = 0.09\ m^2$

For minor-2, $a_0 = Q_{minor-2} / (3 * h^{1/2}) = 0.103 / (3 * 0.58^{1/2}) = 0.05\ m^2$

For minor-3, $a_0 = Q_{minor-3} / (3 * h^{1/2}) = 0.022 / (3 * 0.25^{1/2}) = 0.02\ m^2$

Using the above data, the final gate(s) position(s) will be obtained by using Tables (4.1), (4.2).

Table (4.5), Final gate position in June-3:

	Gate opening [a_0 (m^2)]	Calculated gate position x (cm)	Initial gate position (cm)	Final gate position (cm)
Major canal	0.05	6.90	0	6.90
Minor-1	0.09	12.42	0	12.42
Minor-2	0.05	8.25	0	8.25
Minor-3	0.02	3.30	0	3.30

4.5 Sensors for 'Rewina' canal system:

Table (4.6), Irrigation structure for 'Rewina' canal system:

Minor canal number	Number of Abu-XXs	Minor off-take structure	Minor intermediate structure		Total number of off-take structures
Minor-1	11	WHR/1*0.91	P.R/1*0.91	-	13
Minor-2	6	WHR/1*0.76	-	-	7
Minor-3	11	WHR/1*0.76	9.R/1*0.76	-	13
Minor-4	8	WHR/1*0.76	P.R/1*0.76	-	10
Minor-5	11	WHR/1*0.91	P.R/1*0.91	P.R/1*0.91	14
Minor-6	9	WHR/1*0.76	P.R/1*0.76	-	11
Minor-7	11	WHR/1*0.76	P.R/1*0.76	-	13
Minor-8	9	WHR/1*0.76	P.R/1*0.76	-	11
Minor-9	11	WHR/1*0.76	W.H.R/1*0.76	-	13
Minor-10	9	WHR/1*0.76	P.R/1*0.76	-	11
Minor-11	11	WHR/1*0.76	P.R/1*0.76	-	13
Minor-12	4	WHR/1*0.50	-	-	5

Diameter of field Out let pipe (FOP) is 0.35 cm.

Table (4.7), Sensor for 'Rewina' canal system irrigation structures:

Minor canal	USWL Sensors	DSWL Sensors	Gate positioning Sensors
Minor-1	13	13	13
Minor-2	7	7	7
Minor-3	13	13	13
Minor-4	10	10	10
Minor-5	14	14	14
Minor-6	11	11	11
Minor-7	13	13	13
Minor-8	11	11	11
Minor-9	13	13	13
Minor-10	11	11	11
Minor-11	13	13	13
Minor-12	5	5	5
Total	134	134	134

Table (4.8), Soil moisture sensor for 'Rewina' canal system:

Minor canal number	Number of Abu-XX's	Irrigated area (Fd)	Number of field soil moisture sensors
Minor-1	11	706	71
Minor-2	6	353	36
Minor-3	11	724	73
Minor-4	8	333	34
Minor-5	11	694	70
Minor-6	9	255	26
Minor-7	11	666	67
Minor-8	9	600	60
Minor-9	11	724	73
Minor-10	9	488	49
Minor-11	11	474	48
Minor-12	4	83	9
Total			616

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

5.1 Conclusions:

5.1.1 Traditional Operation of 'Rewina' Canal System:

- The research mainly focused on setting a daily basis operation program for 'Rewina' canal system.
- Total area irrigated by 'Rewina' canal system is 6100 Feddans.
- Irrigation seasons for the grown crops are:

- Ground nuts: From 1st June to the end of October
- Dura: From 1st July to the end of September
- Wheat: From 1st November to the end March
- Cotton: From 1st September to the end January

- Cropping pattern for 'Rewina' canal system is as follows:

Ground Nut	Dura	Wheat	Cotton	Fallow
20 %	20 %	20 %	20 %	20 %

- Area of grown crops for 'Rewina' canal system is as follows:

Ground Nut	Dura	Wheat	Cotton	Fallow
1220 Feddans	1220 Feddans	1220 Feddans	1220 Feddans	1220 Feddans

- The program includes the irrigation schedules, cumulative crop water requirements, irrigation intervals, area irrigated per day and field water requirements for all grown crops, respectively.

- Minimum and maximum monthly irrigation water requirements for 'Rewina' canal systems are 0.50 million m^3/month and 3.46 million m^3/month, respectively.
- Maximum monthly irrigation water requirements occur on October.
- Minimum and maximum daily-irrigated areas for 'Rewina' canal system are 61 Feddans and 271.7 Feddans, respectively.
- Minimum and maximum daily field water requirements for 'Rewina' canal system are 24,400 m^3/day and 108,680 m^3/day, respectively.
- Minimum and maximum daily irrigation water requirements for 'Rewina' canal system are 28,706 m^3/day and 127,859 m^3/day, respectively.
    - Number of irrigations for Ground Nuts, Dura, Wheat and Cotton are 10, 8, 6 and 13, respectively.
    - Irrigation Intervals the grown crops are:

Ground Nuts:	from 13 days to 20 days
Dura:	from 12 days to 22 days
Wheat:	from 15 days to 24 days
Cotton:	from 12 days to 27 days

5.1.2 Towards Automation of 'Rewina' Canal System:

- Input data, monitored by sensors, and transmitted by telecommunication system to the central control room, was analyzed to determine:

ii. The total areas to be irrigated on daily basis,

iii. Discharges required, and

iv. The number of structures to be operated to pass the required discharges.

- The input data used in automation include field moisture contents, upstream and downstream water levels and the initial gate(s) position(s) for each irrigation structure.
- The output data include the final position(s) of gate(s) for each irrigation structure(s), which was executed by the motor(s) erected in each gate.
- Total number of USWL sensors, DSWL sensors and Gate position sensors for 'Rewina' canal system irrigation structures is 134 for all cases.
- Total number of soil moisture sensor for 'Rewina' canal system is 616.

5.2 Recommendations:

- Experimental work for automation of irrigation system should be carried out in the future for better outlook.
- The telecommunication system for the irrigation projects should be studied and combined with the operation of hydraulic structures so that the concept of automation for irrigation systems could be thoroughly understood.
- To increase the efficiency of the existing agricultural schemes and to achieve proper water management especially for vast areas, automation and modern techniques should be introduced.

- In order to achieve good automation process in future it is recommended to study the successful experiences of other countries in the region and entire world, in particular the experiences of Jordan, Egypt and USA.

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Web Site:

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- www.hexatec.com
- www.pubs.asce.org
- www.sutron.com

Annex - 1

Annex - 4

Some Photos for Devices

used in

Automatic Irrigation System

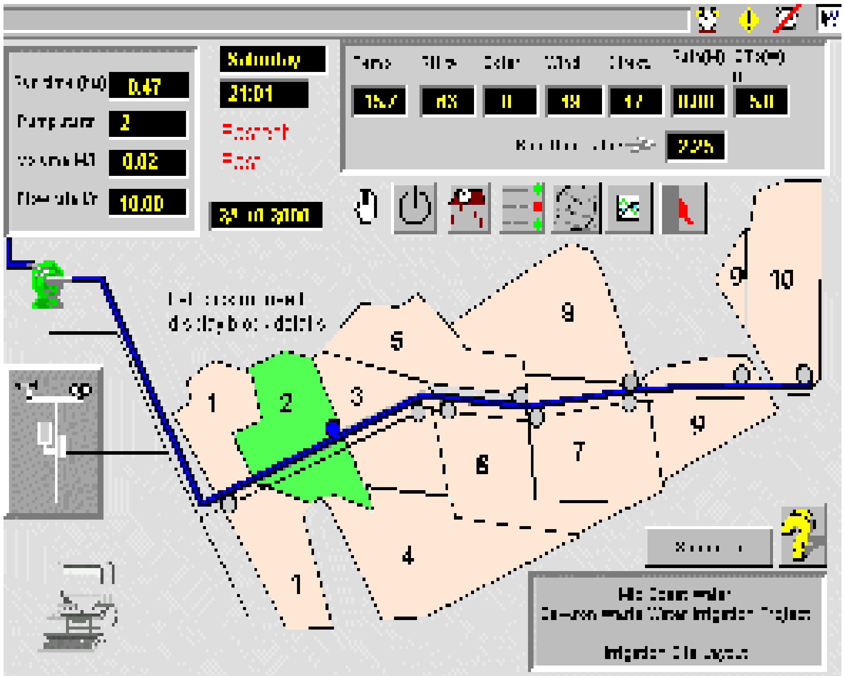


Photo-1: SCADA Software

Photo-2: EIT automatic weather station fitted with land line modem and EIT radio telemetry for local data transmission.

Photo-3: EIT Base station data recorder

This data recorder is positioned centrally to a telemetry network. The EIT data recorder can collect and store information from up to 100 sensors positioned in the field.

Photo-4: The EIT Datatenna unit is a telemetry device with radio module and antenna combined in one sealed unit. The device can be used over short distances to connect remote sensors for various environmental monitoring purposes and was specially developed to provide radio data links to the EnviroSMART soil moisture sensors.

Photo-5: EIT Soil moisture transmitter

Photo-6: Solar powered soil moisture radio transmitter

Photo-7: EIT weather station is used to monitor and compute evaporation at 5-minute intervals

Photo-8: Field control room

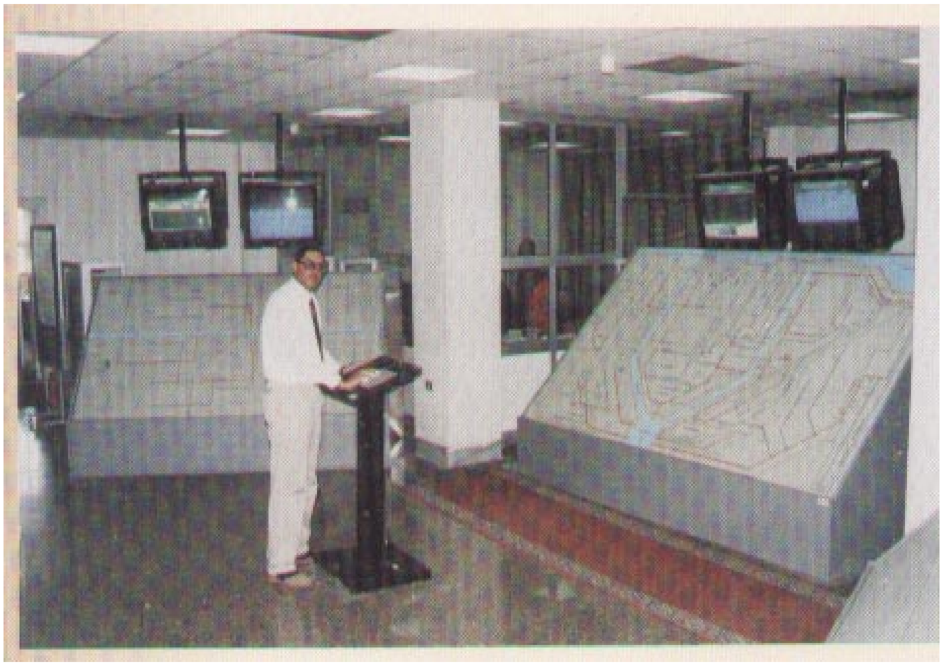
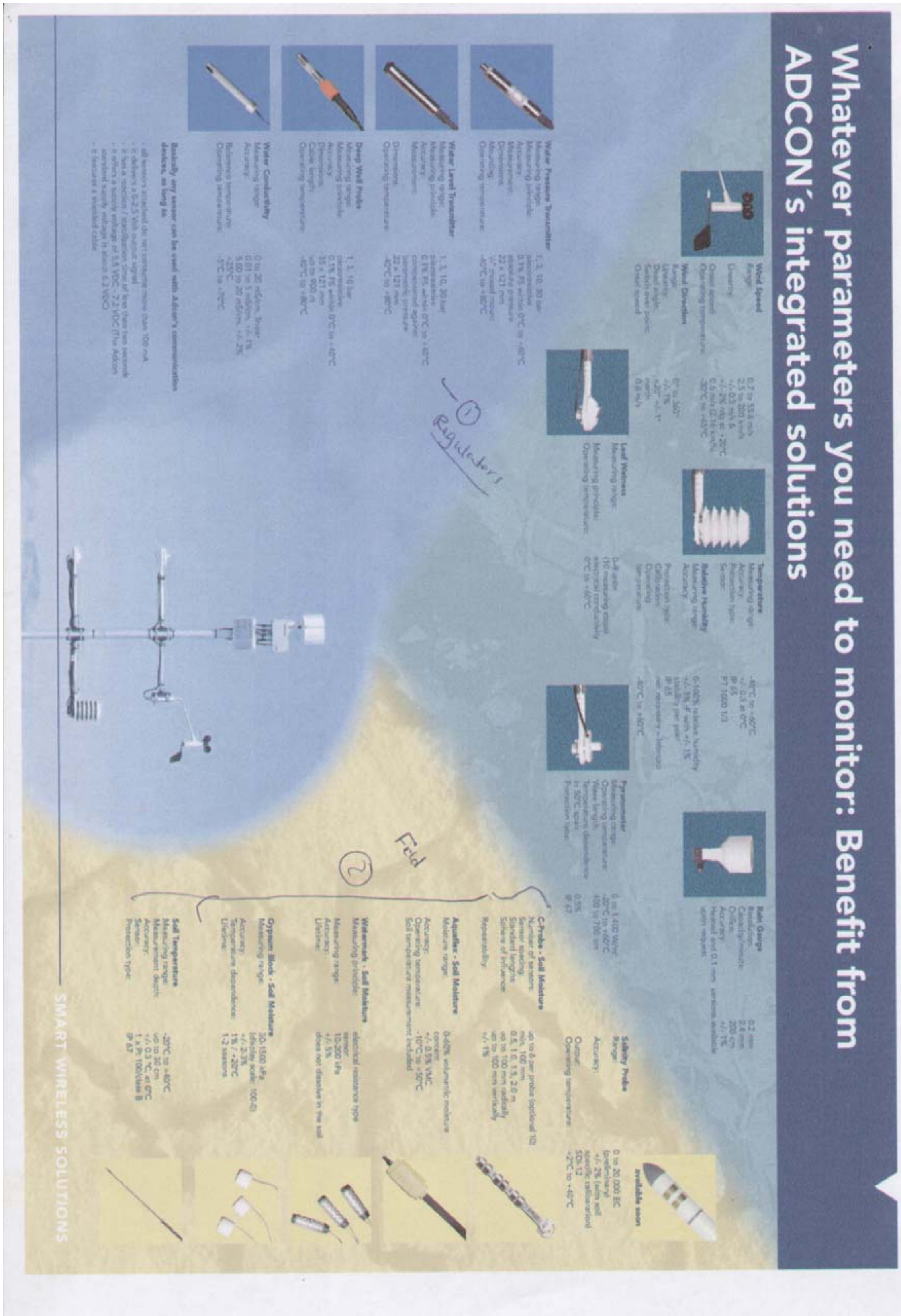


Photo-9: Monitoring room

Photo-10 : Installation of Automatic Gate

Photo-11: Automatic Gate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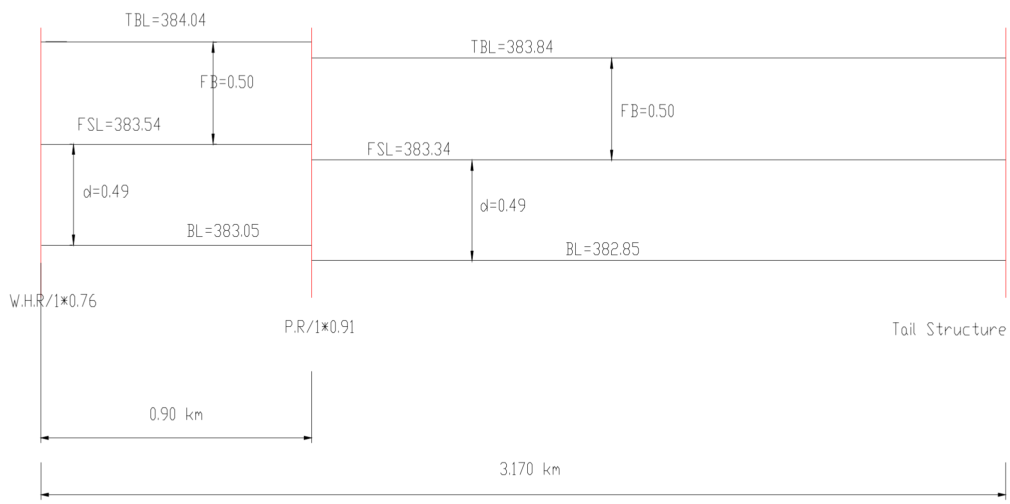
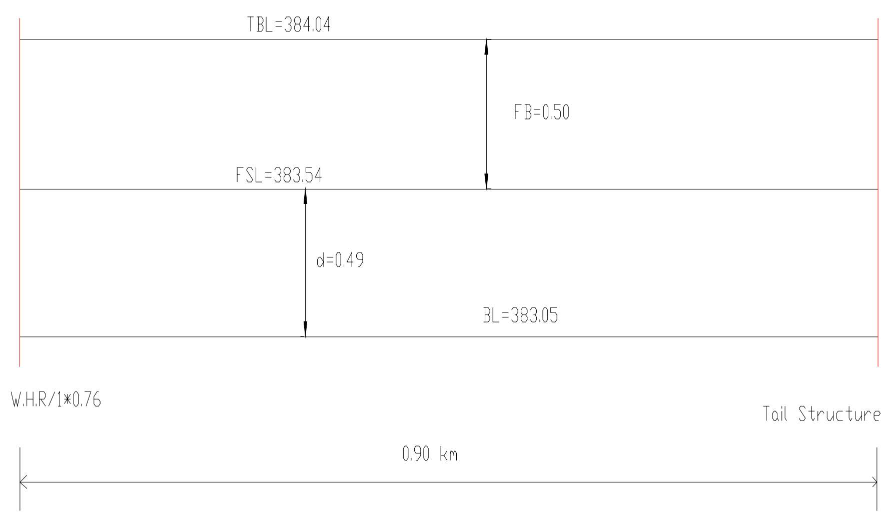
Annex - 5

Minors Canals
Longitudinal Profiles for
Rewina Canal System

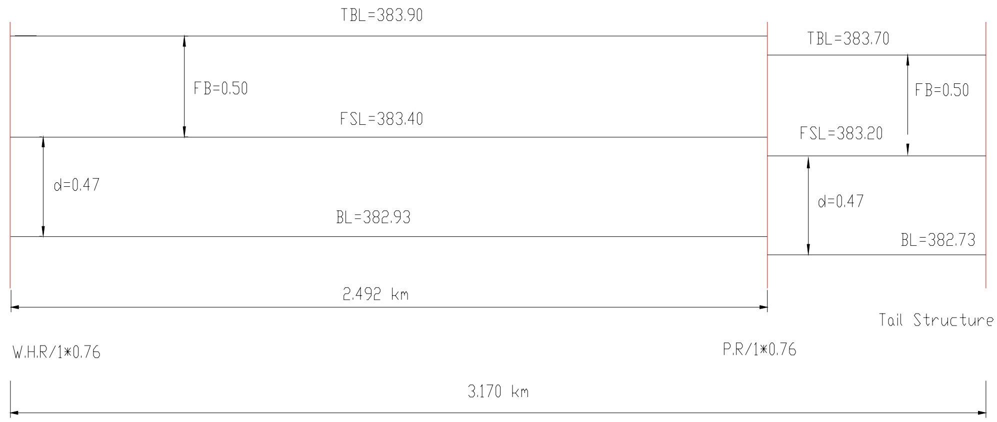
Minor-1: El-khair Wajid minor canal - longitudinal profile



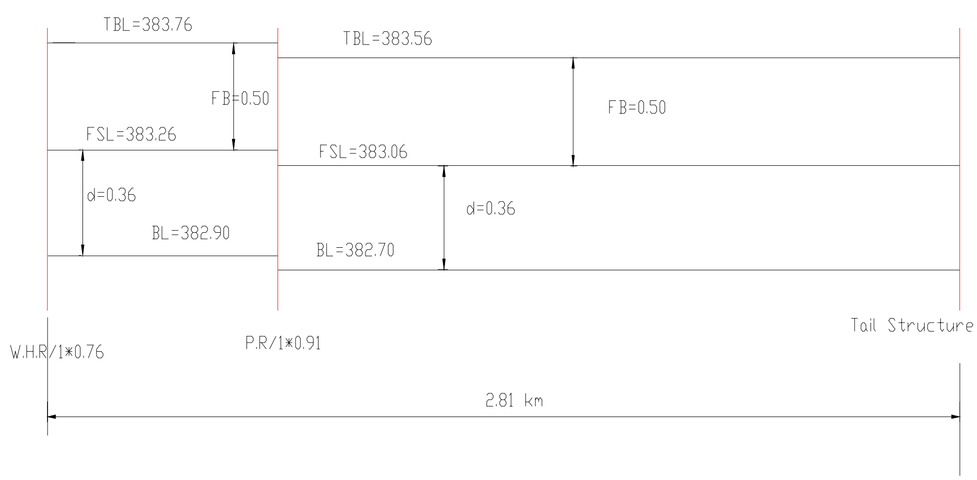
Minor-2: Dabul Abu-Shenab minor canal - longitudinal profile



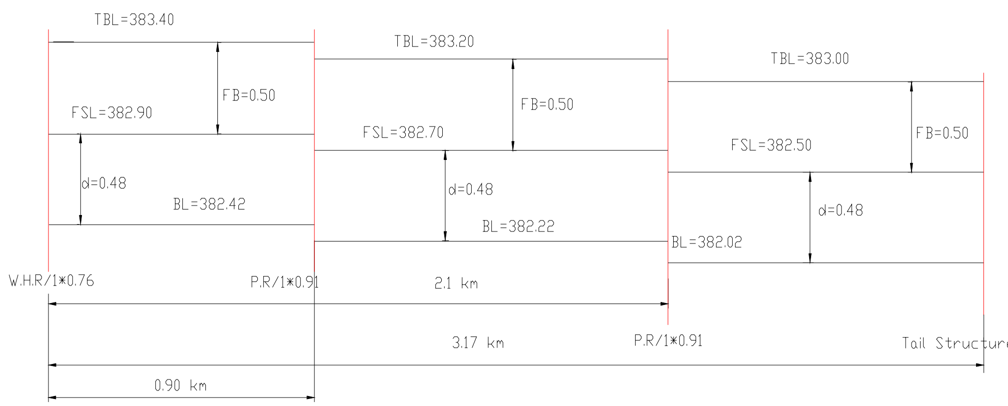
Minor-3 : Um-Kheeren minor canal - longitudinal profile



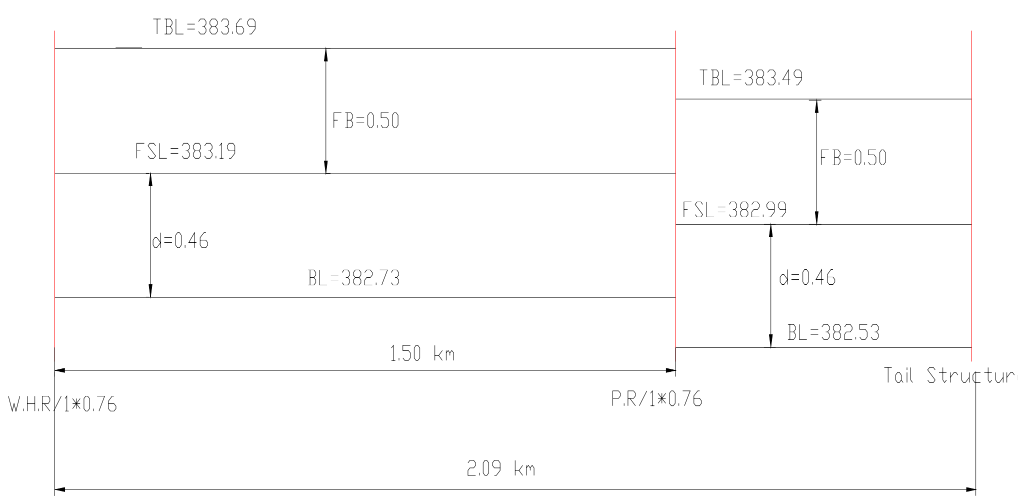
Minor-4: El-Taragma minor canal - longitudinal profile



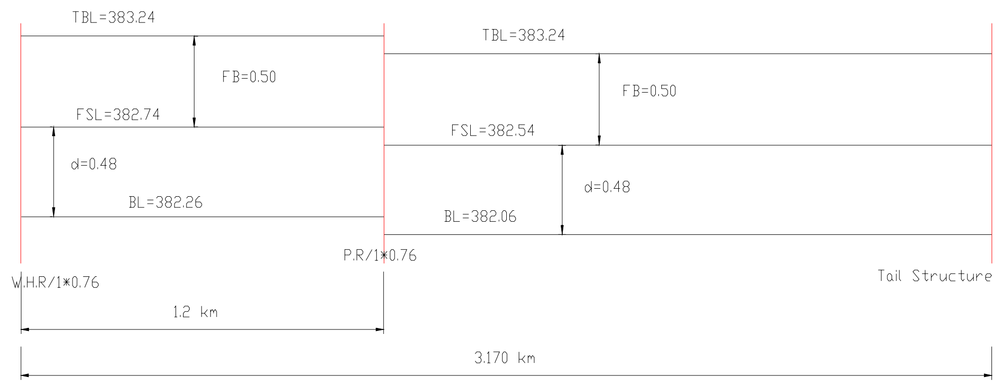
Minor-5: Rewina minor canal - longitudinal profile



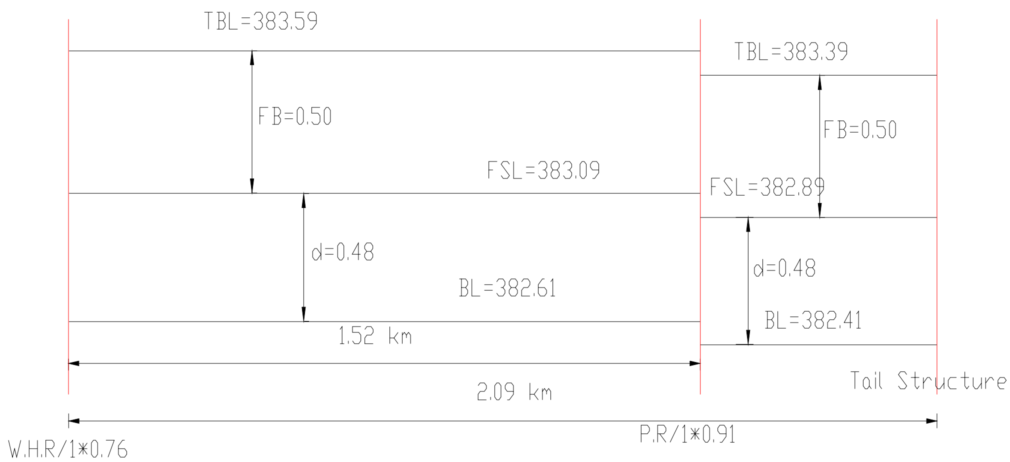
Minor-6: Kaspana minor canal - longitudinal profile



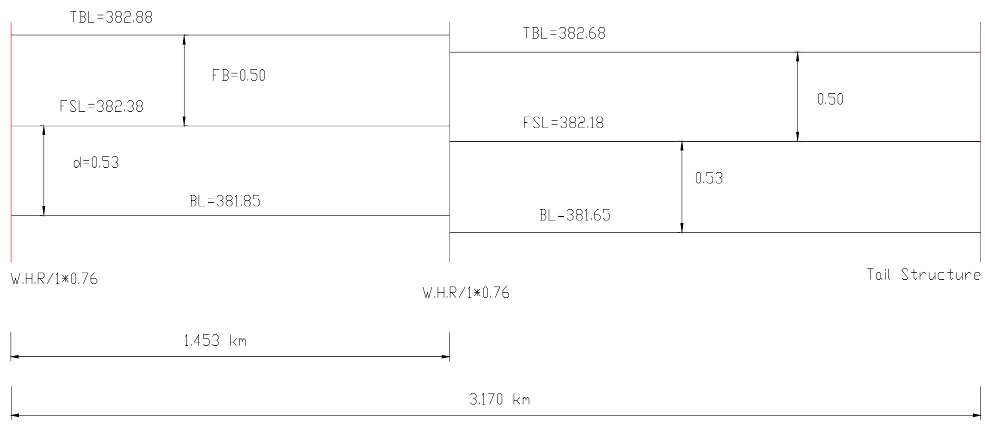
Minor-7: Alla Maana minor canal - longitudinal profile



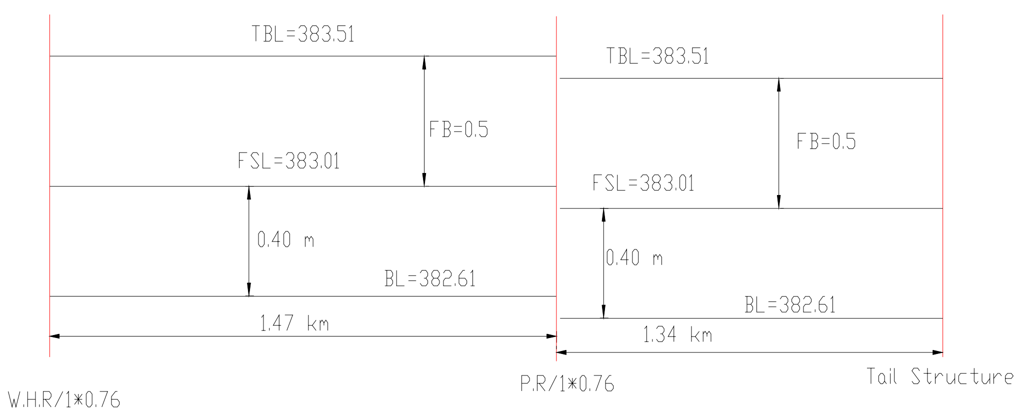
Minor-8: El-Basata minor canal - longitudinal profile



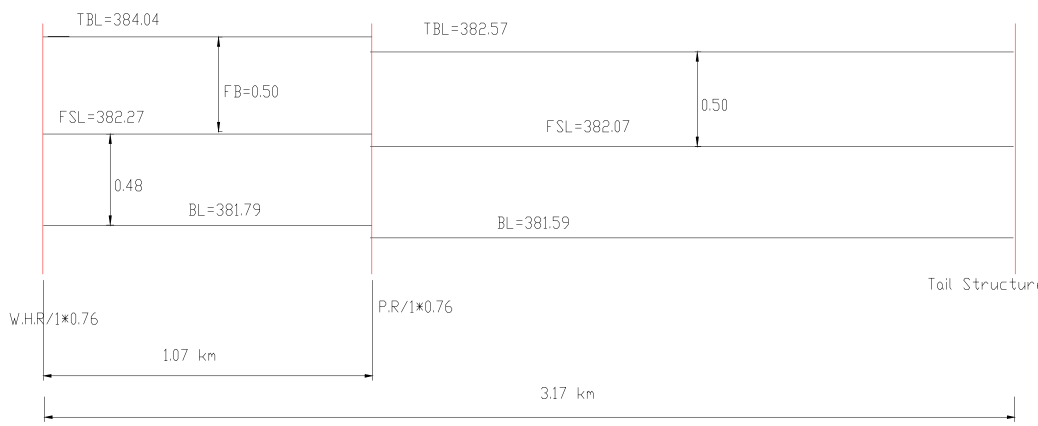
Minor-9: Al-Surraab minor canal - longitudinal profile



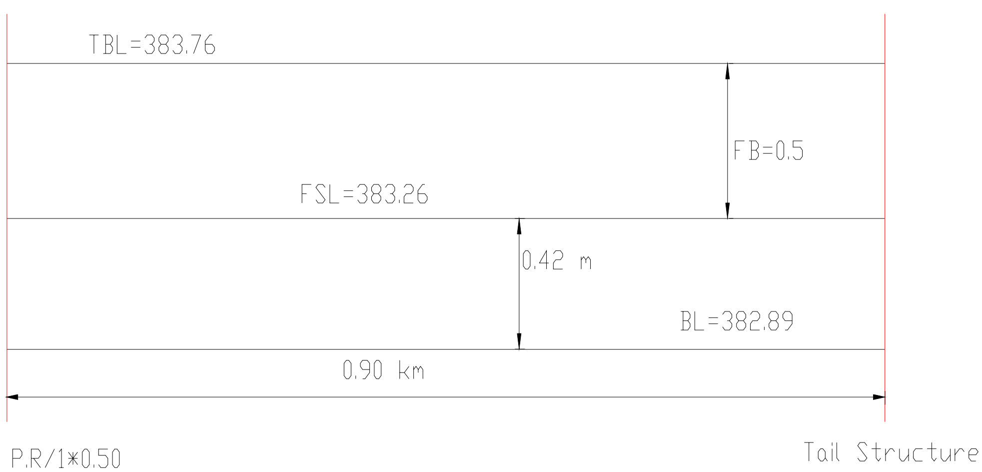
Minor-10: Al-Bardee minor canal - longitudinal profile



Minor-11: Al-Markheat minor canal - longitudinal profile



Minor-12: Dabul Al-Markheat minor canal - longitudinal profile



Annex - 1

Table (2.10): Irrigated areas (in Feddan) per day, for each crop, for 'Rewina' Canal System

Date	Ground Nut	Dura	Cotton	Wheat	**Total**
June – 1	**61**	**-**	**-**	**-**	**61**
2	**61**	**-**	**-**	**-**	**61**
3	**61**	**-**	**-**	**-**	**61**
4	**61**	**-**	**-**	**-**	**61**
5	**61**	**-**	**-**	**-**	**61**
6	**61**	**-**	**-**	**-**	**61**
7	**61**	**-**	**-**	**-**	**61**
8	**61**	**-**	**-**	**-**	**61**
9	**61**	**-**	**-**	**-**	**61**
10	**61**	**-**	**-**	**-**	**61**
June - 11	**61**	**55.5**	**-**	**-**	**116.5**
12	**61**	**55.5**	**-**	**-**	**116.5**
13	**61**	**55.5**	**-**	**-**	**116.5**
14	**61**	**55.5**	**-**	**-**	**116.5**
15	**61**	**55.5**	**-**	**-**	**116.5**
16	**61**	**55.5**	**-**	**-**	**116.5**
17	**61**	**55.5**	**-**	**-**	**116.5**
18	**61**	**55.5**	**-**	**-**	**116.5**
19	**61**	**55.5**	**-**	**-**	**116.5**
20	**61**	**55.5**	**-**	**-**	**116.5**
21	**67.8**	**55.5**	**-**	**-**	**116.5**
22	**67.8**	**55.5**	**-**	**-**	**116.5**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

23	**67.8**	**55.5**	**-**	**-**	**116.5**
24	**67.8**	**55.5**	**-**	**-**	**116.5**
25	**67.8**	**55.5**	**-**	**-**	**116.5**
26	**67.8**	**55.5**	**-**	**-**	**116.5**
27	**67.8**	**55.5**	**-**	**-**	**116.5**
28	**67.8**	**55.5**	**-**	**-**	**116.5**
29	**67.8**	**55.5**	**-**	**-**	**116.5**
30	**67.8**	**55.5**	**-**	**-**	**116.5**
July – 1	**67.8**	**55.5**	**-**	**-**	**123.3**
2	**67.8**	**55.5**	**-**	**-**	**123.3**
3	**67.8**	**76.2**	**-**	**-**	**144**
July - 4	**67.8**	**76.2**	**-**	**-**	**144**
5	**67.8**	**76.2**	**-**	**-**	**144**
6	**67.8**	**76.2**	**-**	**-**	**144**
7	**67.8**	**76.2**	**-**	**-**	**144**
8	**67.8**	**76.2**	**-**	**-**	**144**
9	**76.2**	**76.2**	**-**	**-**	**144**
10	**76.2**	**76.2**	**-**	**-**	**144**
11	**76.2**	**76.2**	**45.2**	**-**	**189.2**
12	**76.2**	**76.2**	**45.2**	**-**	**189.2**
13	**76.2**	**76.2**	**45.2**	**-**	**189.2**
14	**76.2**	**76.2**	**45.2**	**-**	**189.2**
15	**76.2**	**76.2**	**45.2**	**-**	**189.2**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

16	**76.2**	**76.2**	**45.2**	**-**	**189.2**
17	**76.2**	**76.2**	**45.2**	**-**	**189.2**
18	**76.2**	**76.2**	**45.2**	**-**	**189.2**
19	**76.2**	**87.1**	**45.2**	**-**	**208.5**
20	**76.2**	**87.1**	**45.2**	**-**	**208.5**
21	**76.2**	**87.1**	**45.2**	**-**	**208.5**
22	**76.2**	**87.1**	**45.2**	**-**	**208.5**
23	**76.2**	**87.1**	**45.2**	**-**	**208.5**
24	**76.2**	**87.1**	**45.2**	**-**	**208.5**
25	**81.3**	**87.1**	**45.2**	**-**	**208.5**
26	**81.3**	**87.1**	**45.2**	**-**	**208.5**
July - 27	**81.3**	**87.1**	**45.2**	**-**	**208.5**
28	**81.3**	**87.1**	**45.2**	**-**	**208.5**
29	**81.3**	**87.1**	**45.2**	**-**	**208.5**
30	**81.3**	**87.1**	**45.2**	**-**	**208.5**
31	**81.3**	**87.1**	**45.2**	**-**	**208.5**
August – 1	**81.3**	**87.1**	**45.2**	**-**	**208.5**
2	**81.3**	**101.7**	**45.2**	**-**	**223.1**
3	**81.3**	**101.7**	**45.2**	**-**	**223.1**
4	**81.3**	**101.7**	**45.2**	**-**	**228.2**
5	**81.3**	**101.7**	**45.2**	**-**	**228.2**
6	**81.3**	**101.7**	**45.2**	**-**	**228.2**
7	**81.3**	**101.7**	**50.8**	**-**	**233.8**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

8	**81.3**	**101.7**	**50.8**	**-**	**233.8**
9	**93.8**	**101.7**	**50.8**	**-**	**233.8**
10	**93.8**	**101.7**	**50.8**	**-**	**233.8**
11	**93.8**	**101.7**	**50.8**	**-**	**233.8**
12	**93.8**	**101.7**	**50.8**	**-**	**233.8**
13	**93.8**	**101.7**	**50.8**	**-**	**233.8**
14	**93.8**	**87.1**	**50.8**	**-**	**219.2**
15	**93.8**	**87.1**	**50.8**	**-**	**219.2**
16	**93.8**	**87.1**	**50.8**	**-**	**219.2**
17	**93.8**	**87.1**	**50.8**	**-**	**219.2**
18	**93.8**	**87.1**	**50.8**	**-**	**219.2**
August - 19	**93.8**	**87.1**	**50.8**	**-**	**231.7**
20	**93.8**	**87.1**	**50.8**	**-**	**231.7**
21	**93.8**	**87.1**	**50.8**	**-**	**231.7**
22	**93.8**	**87.1**	**50.8**	**-**	**231.7**
23	**93.8**	**87.1**	**50.8**	**-**	**231.7**
24	**93.8**	**87.1**	**50.8**	**-**	**231.7**
25	**93.8**	**87.1**	**50.8**	**-**	**231.7**
26	**93.8**	**87.1**	**50.8**	**-**	**231.7**
27	**93.8**	**87.1**	**50.8**	**-**	**231.7**
28	**93.8**	**101.7**	**50.8**	**-**	**246.3**
29	**93.8**	**101.7**	**50.8**	**-**	**246.3**
30	**93.8**	**101.7**	**50.8**	**-**	**246.3**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

31	**93.8**	**101.7**	**76.2**	**-**	**271.7**
September -1	**93.8**	**101.7**	**76.2**	**-**	**271.7**
2	**93.8**	**101.7**	**76.2**	**-**	**271.7**
3	**93.8**	**101.7**	**76.2**	**-**	**271.7**
4	**87.1**	**101.7**	**76.2**	**-**	**271.7**
5	**87.1**	**101.7**	**76.2**	**-**	**271.7**
6	**87.1**	**101.7**	**76.2**	**-**	**271.7**
7	**87.1**	**101.7**	**76.2**	**-**	**271.7**
8	**87.1**	**101.7**	**76.2**	**-**	**271.7**
9	**87.1**	**67.8**	**76.2**	**-**	**237.8**
10	**87.1**	**67.8**	**76.2**	**-**	**237.8**
September - 11	**87.1**	**67.8**	**76.2**	**-**	**237.8**
12	**87.1**	**67.8**	**76.2**	**-**	**237.8**
13	**87.1**	**67.8**	**76.2**	**-**	**237.8**
14	**87.1**	**67.8**	**76.2**	**-**	**231.1**
15	**87.1**	**67.8**	**76.2**	**-**	**231.1**
16	**87.1**	**67.8**	**93.8**	**-**	**248.7**
17	**87.1**	**67.8**	**93.8**	**-**	**248.7**
18	**81.3**	**67.8**	**93.8**	**-**	**248.7**
19	**81.3**	**67.8**	**93.8**	**-**	**248.7**
20	**81.3**	**67.8**	**93.8**	**-**	**248.7**
21	**81.3**	**67.8**	**93.8**	**-**	**248.7**
22	**81.3**	**67.8**	**93.8**	**-**	**248.7**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

23	**81.3**	**67.8**	**93.8**	**-**	**248.7**
24	**81.3**	**67.8**	**93.8**	**-**	**248.7**
25	**81.3**	**67.8**	**93.8**	**-**	**248.7**
26	**81.3**	**67.8**	**93.8**	**-**	**248.7**
27	**81.3**	**-**	**93.8**	**-**	**180.9**
28	**81.3**	**-**	**93.8**	**-**	**175.1**
29	**81.3**	**-**	**93.8**	**-**	**175.1**
30	**81.3**	**-**	**93.8**	**-**	**175.1**
October – 1	**81.3**	**-**	**93.8**	**-**	**175.1**
2	**81.3**	**-**	**93.8**	**-**	**175.1**
3	**61**	**-**	**93.8**	**-**	**175.1**
October - 4	**61**	**-**	**93.8**	**-**	**175.1**
5	**61**	**-**	**93.8**	**-**	**175.1**
6	**61**	**-**	**93.8**	**-**	**175.1**
7	**61**	**-**	**93.8**	**-**	**175.1**
8	**61**	**-**	**93.8**	**-**	**175.1**
9	**61**	**-**	**93.8**	**-**	**175.1**
10	**61**	**-**	**93.8**	**-**	**175.1**
11	**61**	**-**	**93.8**	**50.8**	**225.9**
12	**61**	**-**	**101.7**	**50.8**	**233.8**
13	**61**	**-**	**101.7**	**50.8**	**213.5**
14	**61**	**-**	**101.7**	**50.8**	**213.5**
15	**61**	**-**	**101.7**	**50.8**	**213.5**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

16	**61**	**-**	**101.7**	**50.8**	**213.5**
17	**61**	**-**	**101.7**	**50.8**	**213.5**
18	**61**	**-**	**101.7**	**50.8**	**213.5**
19	**61**	**-**	**101.7**	**50.8**	**213.5**
20	**61**	**-**	**101.7**	**50.8**	**213.5**
21	**61**	**-**	**101.7**	**50.8**	**213.5**
22	**61**	**-**	**101.7**	**50.8**	**213.5**
23	**-**	**-**	**101.7**	**50.8**	**213.5**
24	**-**	**-**	**93.8**	**50.8**	**205.6**
25	**-**	**-**	**93.8**	**50.8**	**205.6**
26	**-**	**-**	**93.8**	**50.8**	**205.6**
October - 27	**-**	**-**	**93.8**	**50.8**	**205.6**
28	**-**	**-**	**93.8**	**50.8**	**205.6**
29	**-**	**-**	**93.8**	**50.8**	**205.6**
30	**-**	**-**	**93.8**	**50.8**	**205.6**
31	**-**	**-**	**93.8**	**50.8**	**205.6**
November – 1	**-**	**-**	**93.8**	**50.8**	**205.6**
2	**-**	**-**	**93.8**	**50.8**	**144.6**
3	**-**	**-**	**93.8**	**50.8**	**144.6**
4	**-**	**-**	**93.8**	**71.8**	**165.6**
5	**-**	**-**	**93.8**	**71.8**	**165.6**
6	**-**	**-**	**81.3**	**71.8**	**153.1**
7	**-**	**-**	**81.3**	**71.8**	**153.1**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

8	-	-	81.3	71.8	153.1
9	-	-	81.3	71.8	153.1
10	-	-	81.3	71.8	153.1
11	-	-	81.3	71.8	153.1
12	-	-	81.3	71.8	153.1
13	-	-	81.3	71.8	153.1
14	-	-	81.3	71.8	153.1
15	-	-	81.3	71.8	153.1
16	-	-	81.3	71.8	153.1
17	-	-	81.3	71.8	153.1
18	-	-	81.3	71.8	153.1
November - 19	-	-	81.3	71.8	153.1
20	-	-	81.3	71.8	153.1
21	-	-	81.3	81.3	162.6
22	-	-	81.3	81.3	162.6
23	-	-	81.3	81.3	162.6
24	-	-	81.3	81.3	162.6
25	-	-	81.3	81.3	162.6
26	-	-	81.3	81.3	162.6
27	-	-	81.3	81.3	162.6
28	-	-	81.3	81.3	162.6
29	-	-	81.3	81.3	162.6
30	-	-	81.3	81.3	162.6
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

December – 1	**-**	**-**	**81.3**	**81.3**	**162.6**
2	**-**	**-**	**81.3**	**81.3**	**162.6**
3	**-**	**-**	**81.3**	**81.3**	**162.6**
4	**-**	**-**	**81.3**	**81.3**	**162.6**
5	**-**	**-**	**81.3**	**81.3**	**162.6**
6	**-**	**-**	**81.3**	**81.3**	**162.6**
7	**-**	**-**	**81.3**	**81.3**	**162.6**
8	**-**	**-**	**81.3**	**81.3**	**162.6**
9	**-**	**-**	**81.3**	**81.3**	**162.6**
10	**-**	**-**	**81.3**	**81.3**	**162.6**
11	**-**	**-**	**81.3**	**81.3**	**162.6**
December - 12	**-**	**-**	**81.3**	**81.3**	**162.6**
13	**-**	**-**	**81.3**	**81.3**	**162.6**
14	**-**	**-**	**81.3**	**81.3**	**162.6**
15	**-**	**-**	**81.3**	**81.3**	**162.6**
16	**-**	**-**	**81.3**	**81.3**	**162.6**
17	**-**	**-**	**81.3**	**81.3**	**162.6**
18	**-**	**-**	**81.3**	**81.3**	**162.6**
19	**-**	**-**	**81.3**	**81.3**	**162.6**
20	**-**	**-**	**81.3**	**81.3**	**162.6**
21	**-**	**-**	**58.1**	**58.1**	**116.2**
22	**-**	**-**	**58.1**	**58.1**	**116.2**
23	**-**	**-**	**58.1**	**58.1**	**116.2**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

24	-	-	58.1	58.1	116.2
25	-	-	58.1	58.1	116.2
26	-	-	58.1	58.1	116.2
27	-	-	58.1	58.1	116.2
28	-	-	58.1	58.1	116.2
29	-	-	58.1	58.1	116.2
30	-	-	58.1	58.1	116.2
31	-	-	58.1	58.1	116.2
January – 1	-	-	58.1	58.1	116.2
2	-	-	58.1	58.1	116.2
3	-	-	58.1	58.1	116.2
January - 4	-	-	58.1	58.1	116.2
5	-	-	58.1	58.1	116.2
6	-	-	58.1	58.1	116.2
7	-	-	58.1	58.1	116.2
8	-	-	58.1	58.1	116.2
9	-	-	58.1	58.1	116.2
10	-	-	58.1	58.1	116.2
11	-	-	58.1	-	58.1
12	-	-	58.1	-	58.1
13	-	-	58.1	-	58.1
14	-	-	58.1	-	58.1
15	-	-	58.1	-	58.1
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**

16	**-**	**-**	**58.1**	**-**	**58.1**
17	**-**	**-**	**58.1**	**-**	**58.1**
18	**-**	**-**	**58.1**	**-**	**58.1**
19	**-**	**-**	**58.1**	**-**	**58.1**
20	**-**	**-**	**58.1**	**-**	**58.1**
21	**-**	**-**	**58.1**	**-**	**58.1**
21	**-**	**-**	**58.1**	**-**	**58.1**
22	**-**	**-**	**58.1**	**-**	**58.1**
23	**-**	**-**	**58.1**	**-**	**58.1**
24	**-**	**-**	**58.1**	**-**	**58.1**
25	**-**	**-**	**58.1**	**-**	**58.1**
January - 26	**-**	**-**	**58.1**	**-**	**58.1**
27	**-**	**-**	**58.1**	**-**	**58.1**
28	**-**	**-**	**58.1**	**-**	**58.1**
29	**-**	**-**	**58.1**	**-**	**58.1**
30	**-**	**-**	**58.1**	**-**	**58.1**

Annex - 2

Table (2.11): Field water requirements (m^3/day) for the different grown crops for 'Rewina' canal system

Date	Ground nut	ura	otton	heat	otal
June – 1	**24400**				**24400**
2	**24400**	**-**	**-**	**-**	**24400**
3	**24400**	**-**	**-**	**-**	**24400**
4	**24400**	**-**	**-**	**-**	**24400**
5	**24400**	**-**	**-**	**-**	**24400**
6	**24400**	**-**	**-**	**-**	**24400**
7	**24400**	**-**	**-**	**-**	**24400**
8	**24400**	**-**	**-**	**-**	**24400**
9	**24400**	**-**	**-**	**-**	**24400**
10	**24400**	**-**	**-**	**-**	**24400**
11	**24400**	**22200**	**-**	**-**	**46600**
12	**24400**	**22200**	**-**	**-**	**46600**
13	**24400**	**22200**	**-**	**-**	**46600**
14	**24400**	**22200**	**-**	**-**	**46600**
15	**24400**	**22200**	**-**	**-**	**46600**
June - 16	**24400**	**22200**	**-**	**-**	**46600**
17	**24400**	**22200**	**-**	**-**	**46600**
18	**24400**	**22200**	**-**	**-**	**46600**
19	**24400**	**22200**	**-**	**-**	**46600**
20	**24400**	**22200**	**-**	**-**	**46600**
21	**27120**	**22200**	**-**	**-**	**49320**

Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
22	**27120**	**22200**	**-**	**-**	**49320**
23	**27120**	**22200**	**-**	**-**	**49320**
24	**27120**	**22200**	**-**	**-**	**49320**
25	**27120**	**22200**	**-**	**-**	**49320**
26	**27120**	**22200**	**-**	**-**	**49320**
27	**27120**	**22200**	**-**	**-**	**49320**
28	**27120**	**22200**		**-**	**49320**
29	**27120**	**22200**	**-**	**-**	**49320**
30	**27120**	**22200**	**-**	**-**	**49320**
July – 1	**27120**	**22200**	**-**	**-**	**49320**
2	**27120**	**22200**	**-**	**-**	**49320**
3	**27120**	**30480**	**-**	**-**	**57600**
4	**27120**	**30480**	**-**	**-**	**57600**
5	**27120**	**30480**	**-**	**-**	**57600**
6	**27120**	**30480**	**-**	**-**	**57600**
7	**27120**	**30480**	**-**	**-**	**57600**
8	**27120**	**30480**	**-**	**-**	**57600**
July - 9	**30480**	**30480**	**-**	**-**	**60960**
10	**30480**	**30480**	**-**	**-**	**60960**
11	**30480**	**30480**	**18080**	**-**	**79040**
12	**30480**	**30480**	**18080**	**-**	**79040**
13	**30480**	**30480**	**18080**	**-**	**79040**

14	**30480**	**30480**	**18080**	**-**	**79040**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
15	**30480**	**30480**	**18080**	**-**	**79040**
16	**30480**	**30480**	**18080**	**-**	**79040**
17	**30480**	**30480**	**18080**	**-**	**79040**
18	**30480**	**30480**	**18080**	**-**	**79040**
19	**30480**	**34840**	**18080**	**-**	**83400**
20	**30480**	**34840**	**18080**	**-**	**83400**
21	**30480**	**34840**	**18080**	**-**	**83400**
22	**30480**	**34840**	**18080**	**-**	**83400**
23	**30480**	**34840**	**18080**	**-**	**83400**
24	**30480**	**34840**	**18080**	**-**	**83400**
25	**32520**	**34840**	**18080**	**-**	**85440**
26	**32520**	**34840**	**18080**	**-**	**85440**
27	**32520**	**34840**	**18080**	**-**	**85440**
28	**32520**	**34840**	**18080**	**-**	**85440**
29	**32520**	**34840**	**18080**	**-**	**85440**
30	**32520**	**34840**	**18080**	**-**	**85440**
31	**32520**	**34840**	**18080**	**-**	**85440**
August – 1	**32520**	**34840**	**18080**	**-**	**85440**
2	**32520**	**40680**	**18080**	**-**	**91280**
3	**32520**	**40680**	**18080**	**-**	**91280**
4	**32520**	**40680**	**18080**	**-**	**91280**

5	**32520**	**40680**	**18080**	**-**	**91280**
6	**32520**	**40680**	**18080**	**-**	**91280**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
7	**32520**	**40680**	**20320**	**-**	**93520**
8	**32520**	**40680**	**20320**	**-**	**93520**
9	**37520**	**40680**	**20320**	**-**	**98520**
10	**37520**	**40680**	**20320**	**-**	**98520**
11	**37520**	**40680**	**20320**	**-**	**98520**
12	**37520**	**40680**	**20320**	**-**	**98520**
13	**37520**	**40680**	**20320**	**-**	**98520**
14	**37520**	**34840**	**20320**	**-**	**92680**
15	**37520**	**34840**	**20320**	**-**	**92680**
16	**37520**	**34840**	**20320**	**-**	**92680**
17	**37520**	**34840**	**20320**	**-**	**92680**
18	**37520**	**34840**	**20320**	**-**	**92680**
19	**37520**	**34840**	**20320**	**-**	**92680**
20	**37520**	**34840**	**20320**	**-**	**92680**
21	**37520**	**34840**	**20320**	**-**	**92680**
22	**37520**	**34840**	**20320**	**-**	**92680**
23	**37520**	**34840**	**20320**	**-**	**92680**
August - 24	**37520**	**34840**	**20320**	**-**	**92680**
25	**37520**	**34840**	**20320**	**-**	**92680**
26	**37520**	**34840**	**20320**	**-**	**92680**

27	**37520**	**34840**	**20320**	**-**	**92680**
28	**37520**	**40680**	**20320**	**-**	**98520**
29	**37520**	**40680**	**20320**	**-**	**98520**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
30	**37520**	**40680**	**20320**	**-**	**98520**
31	**37520**	**40680**	**30480**	**-**	**108680**
September -1	**37520**	**40680**	**30480**	**-**	**108680**
2	**37520**	**40680**	**30480**	**-**	**108680**
3	**37520**	**40680**	**30480**	**-**	**108680**
4	**34840**	**40680**	**30480**	**-**	**106000**
5	**34840**	**40680**	**30480**	**-**	**106000**
6	**34840**	**40680**	**30480**	**-**	**106000**
7	**34840**	**40680**	**30480**	**-**	**106000**
8	**34840**	**40680**	**30480**	**-**	**106000**
9	**34840**	**27120**	**30480**	**-**	**92440**
10	**34840**	**27120**	**30480**	**-**	**92440**
11	**34840**	**27120**	**30480**	**-**	**92440**
12	**34840**	**27120**	**30480**	**-**	**92440**
13	**34840**	**27120**	**30480**	**-**	**92440**
14	**34840**	**27120**	**30480**	**-**	**92440**
15	**34840**	**27120**	**30480**	**-**	**92440**
September - 16	**34840**	**27120**	**37520**	**-**	**99480**
17	**34840**	**27120**	**37520**	**-**	**99480**

18	**32520**	**27120**	**37520**	**-**	**97160**
19	**32520**	**27120**	**37520**	**-**	**97160**
20	**32520**	**27120**	**37520**	**-**	**97160**
21	**32520**	**27120**	**37520**	**-**	**97160**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
22	**32520**	**27120**	**37520**	**-**	**97160**
23	**32520**	**27120**	**37520**	**-**	**97160**
24	**32520**	**27120**	**37520**	**-**	**97160**
25	**32520**	**27120**	**37520**	**-**	**97160**
26	**32520**	**27120**	**37520**	**-**	**97160**
27	**32520**	**-**	**37520**	**-**	**70040**
28	**32520**	**-**	**37520**	**-**	**70040**
29	**32520**	**-**	**37520**	**-**	**70040**
30	**32520**	**-**	**37520**	**-**	**70040**
October – 1	**32520**	**-**	**37520**	**-**	**70040**
2	**32520**	**-**	**37520**	**-**	**70040**
3	**24400**	**-**	**37520**	**-**	**61920**
4	**24400**	**-**	**37520**	**-**	**61920**
5	**24400**	**-**	**37520**	**-**	**61920**
6	**24400**	**-**	**37520**	**-**	**61920**
7	**24400**	**-**	**37520**	**-**	**61920**
8	**24400**	**-**	**37520**	**-**	**61920**
October - 9	**24400**	**-**	**37520**	**-**	**61920**

10	**24400**	**-**	**37520**	**-**	**61920**
11	**24400**	**-**	**37520**	**20320**	**82240**
12	**24400**	**-**	**40680**	**20320**	**85400**
13	**24400**	**-**	**40680**	**20320**	**85400**
14	**24400**	**-**	**40680**	**20320**	**85400**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
15	**24400**	**-**	**40680**	**20320**	**85400**
16	**24400**	**-**	**40680**	**20320**	**85400**
17	**24400**	**-**	**40680**	**20320**	**85400**
18	**24400**	**-**	**40680**	**20320**	**85400**
19	**24400**	**-**	**40680**	**20320**	**85400**
20	**24400**	**-**	**40680**	**20320**	**85400**
21	**24400**	**-**	**40680**	**20320**	**85400**
22	**24400**	**-**	**40680**	**20320**	**85400**
23	**-**	**-**	**40680**	**20320**	**61000**
24	**-**	**-**	**37520**	**20320**	**57840**
25	**-**	**-**	**37520**	**20320**	**57840**
26	**-**	**-**	**37520**	**20320**	**57840**
27	**-**	**-**	**37520**	**20320**	**57840**
28	**-**	**-**	**37520**	**20320**	**57840**
29	**-**	**-**	**37520**	**20320**	**57840**
30	**-**	**-**	**37520**	**20320**	**57840**
31	**-**	**-**	**37520**	**20320**	**57840**

November – 1	**-**	**-**	**37520**	**20320**	**57840**
2	**-**	**-**	**37520**	**20320**	**57840**
3	**-**	**-**	**37520**	**20320**	**57840**
4	**-**	**-**	**37520**	**28720**	**66240**
5	**-**	**-**	**37520**	**28720**	**66240**
6	**-**	**-**	**32520**	**28720**	**61240**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
7	**-**	**-**	**32520**	**28720**	**61240**
8	**-**	**-**	**32520**	**28720**	**61240**
9	**-**	**-**	**32520**	**28720**	**61240**
10	**-**	**-**	**32520**	**28720**	**61240**
11	**-**	**-**	**32520**	**28720**	**61240**
12	**-**	**-**	**32520**	**28720**	**61240**
13	**-**	**-**	**32520**	**28720**	**61240**
14	**-**	**-**	**32520**	**28720**	**61240**
15	**-**	**-**	**32520**	**28720**	**61240**
16	**-**	**-**	**32520**	**28720**	**61240**
17	**-**	**-**	**32520**	**28720**	**61240**
18	**-**	**-**	**32520**	**28720**	**61240**
19	**-**	**-**	**32520**	**28720**	**61240**
20	**-**	**-**	**32520**	**28720**	**61240**
21	**-**	**-**	**32520**	**32520**	**65040**
22	**-**	**-**	**32520**	**32520**	**65040**

23	**-**	**-**	**32520**	**32520**	**65040**
November - 24	**-**	**-**	**32520**	**32520**	**65040**
25	**-**	**-**	**32520**	**32520**	**65040**
26	**-**	**-**	**32520**	**32520**	**65040**
27	**-**	**-**	**32520**	**32520**	**65040**
28	**-**	**-**	**32520**	**32520**	**65040**
29	**-**	**-**	**32520**	**32520**	**65040**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
30	**-**	**-**	**32520**	**32520**	**65040**
December – 1	**-**	**-**	**32520**	**32520**	**65040**
2	**-**	**-**	**32520**	**32520**	**65040**
3	**-**	**-**	**32520**	**32520**	**65040**
4	**-**	**-**	**32520**	**32520**	**65040**
5	**-**	**-**	**32520**	**32520**	**65040**
6	**-**	**-**	**32520**	**32520**	**65040**
7	**-**	**-**	**32520**	**32520**	**65040**
8	**-**	**-**	**32520**	**32520**	**65040**
9	**-**	**-**	**32520**	**32520**	**65040**
10	**-**	**-**	**32520**	**32520**	**65040**
11	**-**	**-**	**32520**	**32520**	**65040**
12	**-**	**-**	**32520**	**32520**	**65040**
13	**-**	**-**	**32520**	**32520**	**65040**
14	**-**	**-**	**32520**	**32520**	**65040**

15	**-**	**-**	**32520**	**32520**	**65040**
16	**-**	**-**	**32520**	**32520**	**65040**
December - 17	**-**	**-**	**32520**	**32520**	**65040**
18	**-**	**-**	**32520**	**32520**	**65040**
19	**-**	**-**	**32520**	**32520**	**65040**
20	**-**	**-**	**32520**	**32520**	**65040**
21	**-**	**-**	**23240**	**23240**	**46480**
22	**-**	**-**	**23240**	**23240**	**46480**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
23	**-**	**-**	**23240**	**23240**	**46480**
24	**-**	**-**	**23240**	**23240**	**46480**
25	**-**	**-**	**23240**	**23240**	**46480**
26	**-**	**-**	**23240**	**23240**	**46480**
27	**-**	**-**	**23240**	**23240**	**46480**
28	**-**	**-**	**23240**	**23240**	**46480**
29	**-**	**-**	**23240**	**23240**	**46480**
30	**-**	**-**	**23240**	**23240**	**46480**
31	**-**	**-**	**23240**	**23240**	**46480**
January – 1	**-**	**-**	**23240**	**23240**	**46480**
2	**-**	**-**	**23240**	**23240**	**46480**
3	**-**	**-**	**23240**	**23240**	**46480**
4	**-**	**-**	**23240**	**23240**	**46480**
5	**-**	**-**	**23240**	**23240**	**46480**

6	**-**	**-**	**23240**	**23240**	**46480**
7	**-**	**-**	**23240**	**23240**	**46480**
8	**-**	**-**	**23240**	**23240**	**46480**
January - 9	**-**	**-**	**23240**	**23240**	**46480**
10	**-**	**-**	**23240**	**23240**	**46480**
11	**-**	**-**	**23240**	**-**	**23240**
12	**-**	**-**	**23240**	**-**	**23240**
13	**-**	**-**	**23240**	**-**	**23240**
14	**-**	**-**	**23240**	**-**	**23240**
Date	**Ground Nut**	**Dura**	**Cotton**	**Wheat**	**Total**
15	**-**	**-**	**23240**	**-**	**23240**
16	**-**	**-**	**23240**	**-**	**23240**
17	**-**	**-**	**23240**	**-**	**23240**
18	**-**	**-**	**23240**	**-**	**23240**
19	**-**	**-**	**23240**	**-**	**23240**
20	**-**	**-**	**23240**	**-**	**23240**
21	**-**	**-**	**23240**	**-**	**23240**
22	**-**	**-**	**23240**	**-**	**23240**
23	**-**	**-**	**23240**	**-**	**23240**
24	**-**	**-**	**23240**	**-**	**23240**
25	**-**	**-**	**23240**	**-**	**23240**
26	**-**	**-**	**23240**	**-**	**23240**
27	**-**	**-**	**23240**	**-**	**23240**

28	**-**	**-**	**23240**	**-**	**23240**
29	**-**	**-**	**23240**	**-**	**23240**
30	**-**	**-**	**23240**	**-**	**23240**
31	**-**	**-**	**23240**	**-**	**23240**